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**SITE-SPECIFIC TECHNICAL REPORT
FOR FREE PRODUCT RECOVERY
TESTING AT SITE SS-15,
SHAW AFB, SOUTH CAROLINA**

DRAFT



PREPARED FOR:

**AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
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BROOKS AFB, TEXAS 78235-5357**

AND

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DRAFT

SITE-SPECIFIC TECHNICAL REPORT (A003)

for

FREE PRODUCT RECOVERY TESTING AT SITE SS-15, SHAW AFB, SOUTH CAROLINA

by

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for

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21 April 1997

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TABLE OF CONTENTS

| | |
|-----------------------------------------------------------------------|-----|
| LIST OF TABLES | ii |
| LIST OF FIGURES | ii |
| EXECUTIVE SUMMARY | iii |
| 1.0 INTRODUCTION | 1 |
| 1.1 Objectives | 1 |
| 1.2 Testing Approach | 2 |
| 2.0 SITE DESCRIPTION | 2 |
| 3.0 BIOSLURPER SHORT-TERM PILOT TEST METHODS | 4 |
| 3.1 Initial LNAPL/Groundwater Measurements and Baildown Testing | 4 |
| 3.2 Well Construction Details | 5 |
| 3.3 Soil Gas Monitoring Point Installation | 5 |
| 3.4 Soil Sampling and Analysis | 5 |
| 3.5 LNAPL Recovery Testing | 7 |
| 3.5.1 System Setup | 7 |
| 3.5.2 Initial Skimmer Pump Test | 8 |
| 3.5.3 Bioslurper Pump Test | 8 |
| 3.5.4 Second Skimmer Pump Test | 11 |
| 3.5.5 Drawdown Pump Test | 11 |
| 3.5.6 Off-Gas Sampling and Analysis | 12 |
| 3.5.7 Groundwater Sampling and Analysis | 12 |
| 3.6 Bioventing Analyses | 14 |
| 3.6.1 Soil Gas Permeability Testing | 14 |
| 3.6.2 In Situ Respiration Testing | 14 |
| 4.0 RESULTS | 15 |
| 4.1 Baildown Test Results | 15 |
| 4.2 Soil Sample Analyses | 15 |
| 4.3 LNAPL Pump Test Results | 19 |
| 4.3.1 Initial Skimmer Pump Test Results | 19 |
| 4.3.2 Bioslurper Pump Test Results | 19 |
| 4.3.3 Second Skimmer Pump Test | 19 |
| 4.3.4 Drawdown Pump Test | 23 |
| 4.3.5 Extracted Groundwater, LNAPL, and Off-Gas Analyses | 23 |
| 4.4 Bioventing Analyses | 25 |
| 4.4.1 Soil Gas Permeability and Radius of Influence | 25 |
| 4.4.2 In Situ Respiration Test Results | 25 |
| 5.0 DISCUSSION AND CONCLUSIONS | 25 |

| | |
|----------------------------------------------------------------------------------------------------------|-----|
| 6.0 REFERENCES | 31 |
| APPENDIX A: SITE-SPECIFIC TEST PLAN FOR BIOSLURPER FIELD ACTIVITIES AT SHAW AFB, SOUTH CAROLINA | A-1 |
| APPENDIX B: LABORATORY ANALYTICAL REPORTS | B-1 |
| APPENDIX C: SYSTEM CHECKLIST | C-1 |
| APPENDIX D: DATA SHEETS FROM THE SHORT-TERM PILOT TEST | D-1 |
| APPENDIX E: SOIL GAS PERMEABILITY TEST RESULTS | E-1 |
| APPENDIX F: IN SITU RESPIRATION TEST RESULTS | F-1 |

LIST OF TABLES

| | | |
|-----------|----------------------------------------------------------------------------|----|
| Table 1. | Initial Soil-Gas Compositions at Site SS-15 | 7 |
| Table 2. | Baildown Test Results at Monitoring Well MW 634 | 16 |
| Table 3. | Baildown Test Results at Monitoring Well MW 644 | 17 |
| Table 4. | TPH and BTEX Concentrations in Soil Samples | 18 |
| Table 5. | Physical Characterization of Soil Samples | 18 |
| Table 6. | Pump Test Results at Monitoring Well MW 644 | 20 |
| Table 7. | BTEX and TPH Concentrations in Extracted Groundwater During Pump Tests .. | 24 |
| Table 8. | BTEX and TPH Concentrations in Off-Gas During the Bioslurper Pump Test ... | 24 |
| Table 9. | BTEX Concentrations in LNAPL | 26 |
| Table 10. | C-Range Compounds in LNAPL | 26 |

LIST OF FIGURES

| | | |
|-----------|----------------------------------------------------------------------------------------------------------------------------|----|
| Figure 1. | Site Map Showing the Location of Monitoring Wells | 3 |
| Figure 2. | Schematic Diagram Showing Constructions Details of Monitoring Well MW 644 and Adjacent Soil Gas Monitoring Points | 6 |
| Figure 3. | Drop Tube Placement and Valve Position During the Skimmer Pump Test | 9 |
| Figure 4. | Drop Tube Placement and Valve Position During the Bioslurper Pump Test | 10 |
| Figure 5. | Drop Tube Placement and Valve Position for the Drawdown Pump Test | 13 |
| Figure 6. | LNAPL Recovery Versus Time During Each Pump Test | 21 |
| Figure 7. | LNAPL Recovery Rate Versus Time During the Bioslurper Pump Test | 22 |
| Figure 8. | Distribution of C-Range Compounds in LNAPL | 27 |
| Figure 9. | Radius of Influence Determination Using Soil Gas Pressure Change Versus Distance From Extraction Well | 28 |

EXECUTIVE SUMMARY

This report summarizes the field activities conducted at Shaw Air Force Base (AFB) for a short-term field pilot test to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery techniques used to remove light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at Shaw AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe, and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The test at Shaw is one of more than 40 similar field tests to be conducted at various locations throughout the United States and its possessions.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping technology for removal of free product and remediation of the contaminated area. The on-site testing is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The three LNAPL recovery technologies tested at Shaw AFB were skimmer pumping, bioslurping, and drawdown pumping.

Bioslurper pilot test activities were conducted at monitoring well MW 644. Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing to evaluate the mobility of LNAPL, soil sampling to determine physical/chemical site characteristics, soil gas permeability testing to determine the radius of influence, and in situ respiration testing to evaluate site microbial activity.

Following the site characterization activities, the pump tests were conducted. At monitoring well MW 644, pilot tests for skimmer pumping, bioslurping, and drawdown pumping were

conducted. The LNAPL recovery testing was conducted in the following sequence at monitoring well MW 644: 48 hr in the skimmer configuration, 101.5 hr in the bioslurper configuration, an additional 23 hr in the skimmer configuration, and 28 hr in the drawdown configuration.

Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

Baildown recovery tests were conducted at monitoring wells MW 634 and MW 644. Baildown recovery tests provide a qualitative indication of the presence of mobile, free-phase LNAPL and recovery potential. Overall, the baildown recovery tests indicated a relatively high rate of LNAPL recovery into the wells. At monitoring well MW 644, LNAPL recovered to within 70% of initial levels by the end of the 4 hr baildown test. At monitoring well MW 634, LNAPL recovered to a level approximately 50% of the initial LNAPL thickness. Based on these results, pilot testing was initiated on monitoring well MW 644.

Direct pumping tests were conducted at monitoring well MW 644. Skimmer pump testing was conducted at monitoring well MW 644 in a continuous extraction mode for two days. A significant quantity of LNAPL was recovered during this pump test. The initial LNAPL recovery rate was 23.5 gallons/day, which dropped to 14.5 gallons/day by the second day of testing. A total of approximately 390 gallons of groundwater was produced with an average production rate of 200 gallons/day. LNAPL recovery was significantly greater during the bioslurper pump test than that observed during the skimmer pump test. Bioslurper testing was conducted for approximately four days, resulting in relatively high recovery on the first day (46 gallons/day), with a significant reduction in recovery by day 2 to 28 gallons/day. However, by day 3, LNAPL recovery rates increased to 37 gallons/day, and remained relatively constant for the remainder of the testing. This increase on day 3 corresponds to increasing the pump vacuum and a corresponding increase in vapor flowrate and well vacuum. A total of 150 gallons of LNAPL and 1,240 gallons of groundwater was extracted, with daily average recovery rates of 38 gallons/day for LNAPL and 320 gallons/day for groundwater.

LNAPL recovery rates during the second skimmer pump test were similar to the initial skimmer pump test during approximately 23 hours of continuous pumping. Approximately 21 gallons of LNAPL and 180 gallons of groundwater were recovered during the second skimmer pump test, with daily average recovery rates of 22 and 190 gallons/day, respectively. These results demonstrate

that operation of the bioslurper system in the skimmer mode was an effective means of free-product recovery, although recovery rates are significantly lower than during bioslurping.

Drawdown pump testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed 22 inches below the static water table in monitoring well MW 644. Significant quantities of LNAPL were recovered, with average rates of 30 gallons/day and a total recovery of approximately 54 gallons. Groundwater production rates were on the order of 240 gallons/day, with a total of approximately 440 gallons produced. These results demonstrate that the vacuum gradient maintained during the bioslurper test resulted in higher fluid recovery rates than the 22 inch-groundwater drawdown test.

Bioslurping also promotes mass removal in the form of in situ biodegradation via bioventing and soil gas extraction. Vapor phase mass removal is the result of soil gas extraction as well as volatilization that occurs during the movement of LNAPL free product through the extraction network. Given a flowrate of 12.5 scfm and using an average concentration of 12,500 ppmv TPH and 1,300 ppmv benzene, approximately 65 lb/day of TPH and 4.7 lb/day of benzene were emitted to the air. Thus, mass removal in the vapor phase is significant. Higher vapor mass removal rates are more often sustained at those sites where liquid product recovery is sustained.

The initial soil gas profiles at the site displayed oxygen-deficient, carbon dioxide-rich, high total volatile hydrocarbon vapor conditions at depths from 30 to 40 ft bgl. These conditions indicate that natural biodegradation of residual petroleum hydrocarbons has occurred, but is limited by oxygen availability. Soil gas concentrations were measured during the bioslurper test at monitoring points adjacent to monitoring well MW 644 to determine if the vadose zone was being oxygenated via the bioslurper action. Unfortunately, results were inconclusive based on oxygen measurements, although soil gas permeability testing indicated that a radius of influence of approximately 40 ft could be achieved. In general, it is our experience that oxygenation will occur at monitoring points where a perceptible pressure change is measured. In situ biodegradation rates 0.025 to 21 mg/kg-day were measured at four different locations. Based on the radius of influence of 40 ft and a hydrocarbon-impacted soil thickness of 40 ft, mass removal rates via biodegradation are on the order of 0.43 to 370 lbs of hydrocarbon per day. Thus, mass removal rates via biodegradation could be more significant than the vapor phase removal rates measured during the bioslurper test. These results indicate that bioventing is feasible at this site. Air injection bioventing is preferable over bioslurping and soil vapor extraction with respect to the elimination of hydrocarbon vapor emissions.

In summary, the on-site testing at Site SS-15, Shaw AFB, included the direct testing of gravity-driven and vacuum-driven LNAPL free product recovery techniques, bioventing, physical sampling, and tests relevant to soil vapor extraction. Liquid phase recovery was sustainable during all pump tests, with the highest recoveries during bioslurping. The in situ respiration test and vadose zone radius of influence testing demonstrate that bioventing may be feasible at this site. Bioslurping appears to be a suitable recovery technique for this site.

DRAFT SITE-SPECIFIC TECHNICAL REPORT (A003)
for
FREE PRODUCT RECOVERY TESTING AT SITE SS-15,
SHAW AFB, SOUTH CAROLINA

21 April 1997

1.0 INTRODUCTION

This report describes activities performed and data collected during field tests at Shaw Air Force Base (AFB), South Carolina to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery technologies for removal of light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at Shaw AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper Initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

1.1 Objectives

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The test at Shaw AFB is one of more than 40 similar field tests to be conducted at various locations throughout the United States and its possessions. Aspects of the testing program that apply to all sites are described in the Test Plan and Technical Protocol for Bioslurping (Battelle, 1995). Test provisions specific to activities at Shaw AFB are described in the Site-Specific Test Plan provided in Appendix A.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping

technology for removal of free product and remediation of the contaminated area. The on-site testing is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The three LNAPL recovery technologies tested at Shaw AFB were skimmer pumping, bioslurping, and drawdown pumping. The specific test objectives, methods, and results for the Shaw AFB test program are discussed in the following sections.

1.2 Testing Approach

Bioslurper pilot test activities were conducted at monitoring well MW 644. Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing to evaluate the mobility of LNAPL, soil sampling to determine physical/chemical site characteristics, soil gas permeability testing to determine the radius of influence, and in situ respiration testing to evaluate site microbial activity.

Following the site characterization activities, the pump tests were conducted. At monitoring well MW 644, pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted. The LNAPL recovery testing was conducted in the following sequence at monitoring well MW 644: 48 hr in the skimmer configuration, 101.5 hr in the bioslurper configuration, an additional 23 hr in the skimmer configuration, and 28 hr in the drawdown configuration.

Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

2.0 SITE DESCRIPTION

Shaw AFB is located in central South Carolina. The site under investigation at Shaw AFB is Operable Unit 1 (OU-1), IRP Site SS-15. The organic liquid contaminant is JP-4 jet fuel, and the primary source of contamination appears to be the underground storage tank farms. Figure 1 shows the OU-1 site, including monitoring well locations and the extent of the free-product plume. The area

under consideration for bioslurping activities is the smaller circular plume located to the south of the two adjoining larger plumes. From these data, the wells that are most likely to yield significant amounts of free product have been identified. Wells MW-634 and MW-644 had fuel thicknesses of 6.85 ft and 6.71 ft, respectively, when measured on January 14, 1996. Measurements taken February 23, 1996, revealed decreased thicknesses of 1.31 ft and 5.64 ft at respective wells MW-634 and MW-644. Depth to product at the two wells ranged from 41 to 44 ft bgs and depth to water from 46 to 49 ft bgs during the January/February 1996 readings.

Preliminary soil analytical results from wells in the area under investigation revealed BTEX concentrations ranging from 29 to 158 mg/kg and TPH concentrations ranging from 27 to 3,700 mg/kg. Groundwater analysis data is limited to samples taken from the POL Yard area, where the BTEX concentration in groundwater was found to be approximately 5 ppm and the benzene concentration approximately 1.4 ppm.

Polycyclic aromatic hydrocarbons (PAHs) have also been found to be present at the POL Yard site. Previous analyses of the groundwater have revealed the presence of four PAHs — acenaphthene, naphthalene, methylnaphthalene, and fluorene. However, all previous analyses of the site soils and groundwater have indicated that the main source of contamination at the POL Yard site is the free-product plume of JP-4 jet fuel.

3.0 BIOSLURPER SHORT-TERM PILOT TEST METHODS

This section documents the initial conditions at the test site and describes the test equipment and methods used for the short-term pilot test at Shaw AFB.

3.1 Initial LNAPL/Groundwater Measurements and Baildown Testing

Monitoring wells MW 644 and MW 643 were evaluated for use in the bioslurper pilot testing. Initial depths to LNAPL and to groundwater were measured using an oil/water interface probe (ORS Model #1068013). LNAPL was removed from the well with a Teflon® bailer until the LNAPL thickness could no longer be reduced. The rate of increase in the thickness of the floating LNAPL layer was monitored using the oil/water interface probe for approximately 5 hr at monitoring well MW 634 and for approximately 4 hr at monitoring well MW 644.

3.2 Well Construction Details

Short-term bioslurper pump tests were conducted at existing monitoring well MW 644. Monitoring well MW 644 is constructed of 4-inch-diameter, schedule 80 polyvinyl chloride (PVC). Total well depth is 49 ft with a screen length of 10.0 ft. A schematic diagram illustrating general well construction details for monitoring well MW 644 is provided in Figure 2.

3.3 Soil Gas Monitoring Point Installation

Three monitoring points were installed and labeled MPA, MPB, MPC, and MPD. The locations and constructions details of the monitoring points are illustrated in Figure 2.

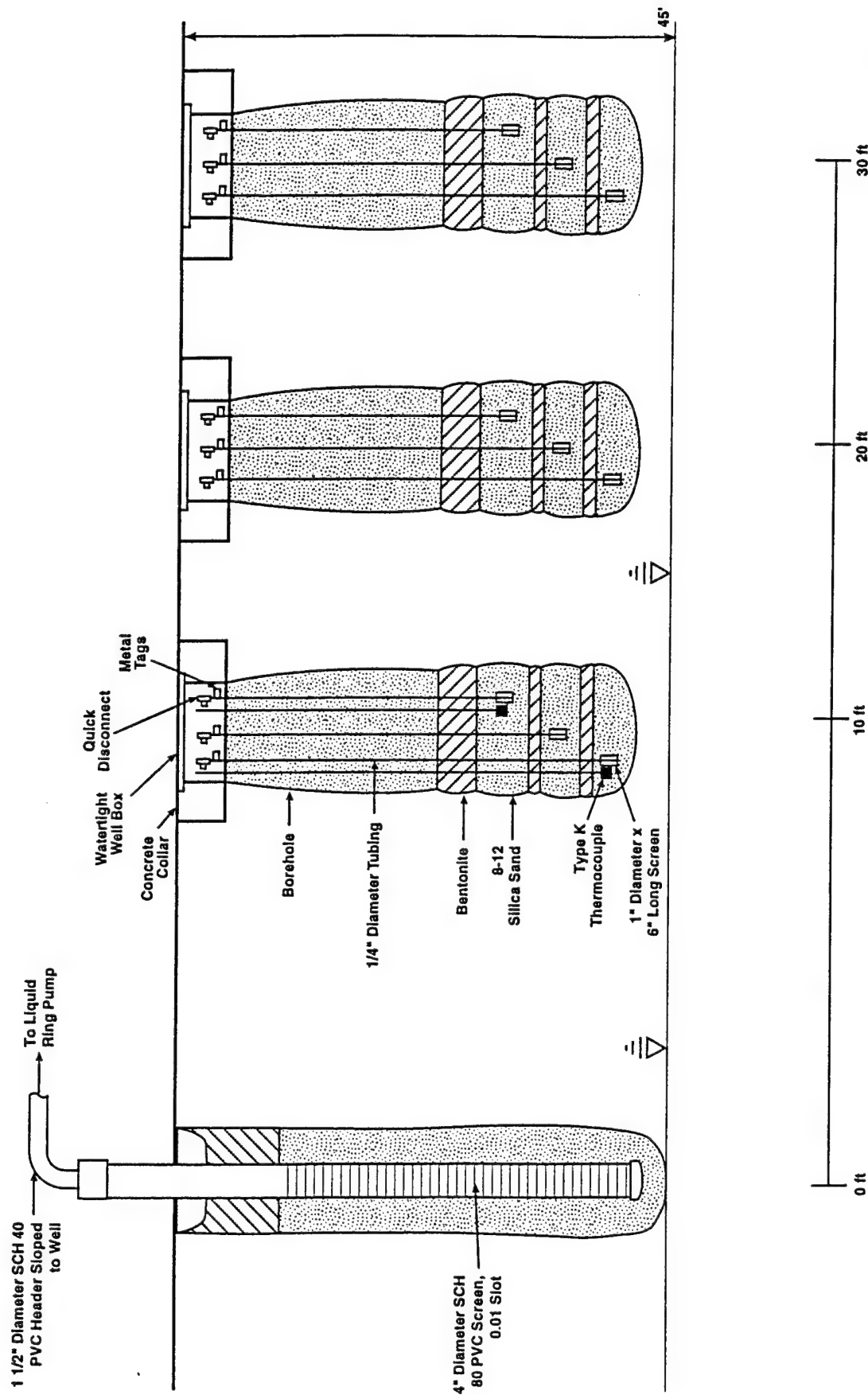
The monitoring points consisted of 1/4-inch tubing, with 1-inch-diameter, 6-inch-long screened areas. The screened lengths were positioned at depths of 30, 35, and 40 ft bgl at monitoring point MPA, MPB, and MPC, and at a depth of 16 ft bgl at monitoring point MPD. The annular space corresponding to the screened length was filled with silica sand. The interval from the top of the screened length to the bottom of the next screened length, as well as the interval from the ground surface to the top of the first screened length, was filled with bentonite clay chips. After placement, the bentonite clay was hydrated with water to expand the chips and provide a seal.

Type K thermocouples were installed with monitoring point MPC at depths of 30 and 40 ft bgl.

After installation of the monitoring points, initial soil gas measurements were taken with a GasTech portable O₂/CO₂ meter and a GasTech TraceTechtor portable hydrocarbon meter. Oxygen limitation was observed at all monitoring points, with oxygen concentrations below 5% at all depths. TPH concentrations were greater than 20,000 ppmv at all monitoring point screened intervals (Table 1). Monitoring point MPD was installed later in the testing; therefore, no initial data is shown.

3.4 Soil Sampling and Analysis

Two soil samples were collected during the installation of monitoring point MPB and were labeled SHW-S-1 and SHW-S-2. Sample SHW-S-1 was collected from 38 to 40 ft bgl and sample SHW-S-2 was collected from 40 to 42 ft bgl using a split spoon sampler with brass sleeves. The samples were placed in an insulated cooler, chain-of-custody records and shipping papers were



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Figure 2. Schematic Diagram Showing Constructions Details of Monitoring Well MW 644 and Adjacent Soil Gas Monitoring Points

Table 1. Initial Soil-Gas Compositions at Site SS-15

| Monitoring Point | Depth (ft) | Oxygen (%) | Carbon Dioxide (%) | TPH (ppmv) |
|------------------|------------|------------|--------------------|------------|
| MPA | 30 | 6.5 | 7.0 | > 20,000 |
| | 35 | 3.0 | 9.0 | > 20,000 |
| | 40 | 1.0 | 11 | > 20,000 |
| MPB | 30 | 2.5 | 9.0 | > 20,000 |
| | 35 | 2.0 | 9.5 | > 20,000 |
| | 40 | 1.0 | 9.5 | > 20,000 |
| MPC | 30 | 2.0 | 9.0 | > 20,000 |
| | 35 | 0.5 | 10 | > 20,000 |
| | 40 | 2.5 | 8.5 | > 20,000 |

completed, and the samples were sent to Alpha Analytical, Inc., in Sparks, Nevada. Samples were analyzed for BTEX, bulk density, moisture content, particle size, porosity, and TPH. The laboratory analytical report is provided in Appendix B.

3.5 LNAPL Recovery Testing

3.5.1 System Setup

The bioslurping pilot test system is a trailer-mounted mobile unit. The vacuum pump (Atlantic Fluidics Model A100, 7.5-hp liquid ring pump), filter box, oil/water separator, and required support equipment were carried to the test location on a trailer. The trailer was located near the monitoring well, the well cap was removed, a well seal was placed on the top of the well, and the slurper tube was lowered into the well. The slurper tube was attached to the vacuum pump. Different configurations of the well seal and the placement depth of the slurper tube allow for simulation of skimmer pumping, operation in the bioslurping configuration, or simulation of drawdown pumping. Extracted soil gas was discharged into the atmosphere. Extracted groundwater

was treated by passing the recovered fluid through the filter box, the oil/water separators, and a settling tank. The groundwater was then discharged into the base's treatment plant.

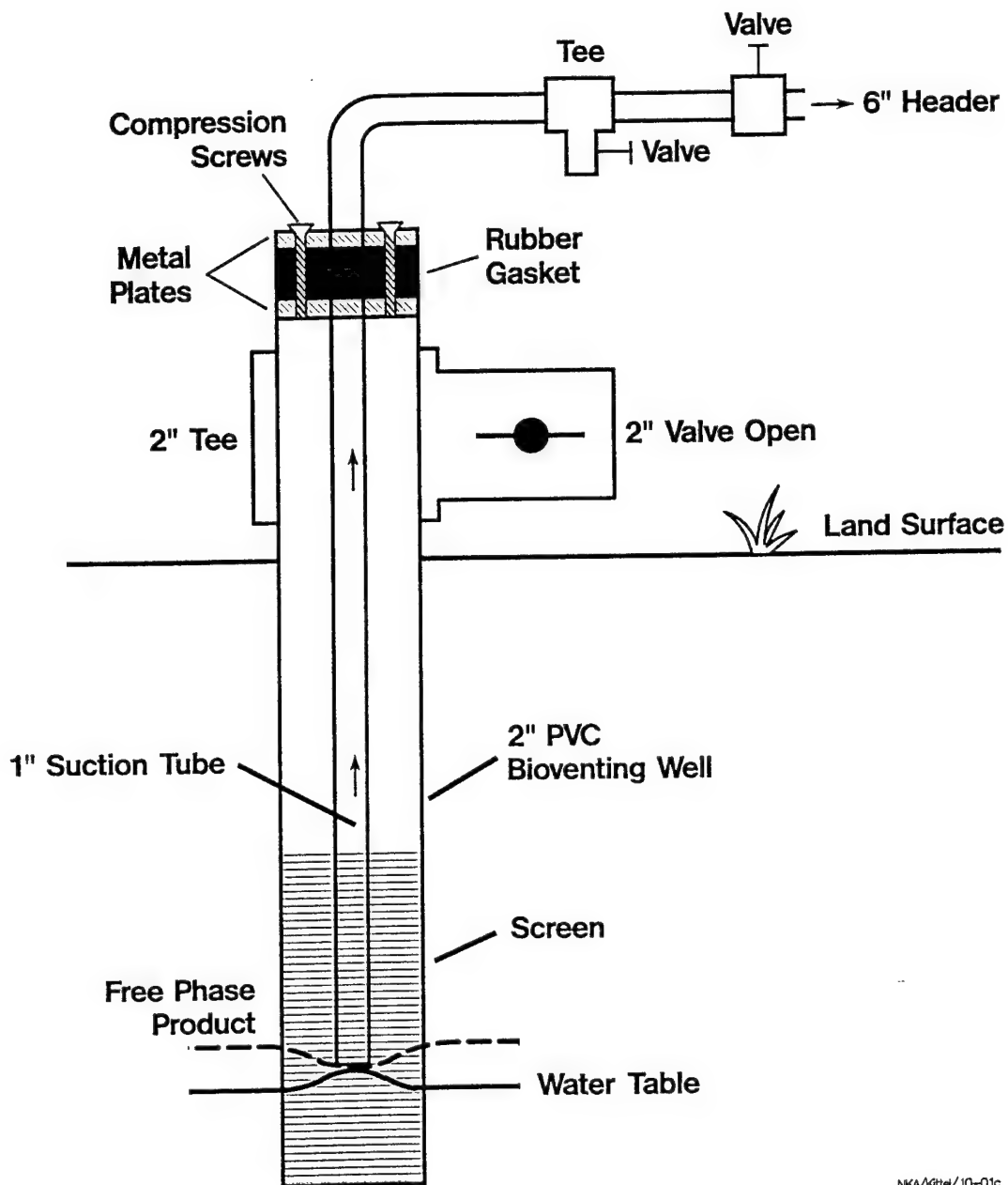
A brief system startup test was performed prior to LNAPL recovery testing to ensure that all system components were working properly. The system checklist is provided in Appendix C. All site data and field testing information were recorded in a field notebook and then transcribed onto pilot test data sheets provided in Appendix D.

3.5.2 Initial Skimmer Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. The liquid ring pump was used to conduct the skimmer pump test. The slurper tube was set at the oil/water interface. The drop tube was held in position by the well seal, and was positioned to leave the wellhead vented to the atmosphere (Figure 3). The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started at 11:48 am, 9 July 1996, to begin the second skimmer pump test. The pump vacuum was approximately 16"Hg and the vapor flowrate was approximately 32 scfm. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

3.5.3 Bioslurper Pump Test

Upon completion of the skimmer pump test, preparations were made to begin the bioslurper pump test. The LNAPL and groundwater depth were measured prior to any recovery testing. The slurper tube was set at the LNAPL/groundwater interface. The sanitary well seal was positioned inside the well, sealing the wellhead and allowing the pump to establish a vacuum in the well (Figure 4). A pressure gauge was installed at the wellhead to measure the vacuum inside the extraction well. The liquid ring pump was started at 12 pm, 11 July 1996, to begin the bioslurper pump test. The test was initiated approximately 0.5 hr after the skimmer pump test and was operated for 101.5 hr. Approximately 83 hr after test initiation, the liquid ring pump shut down for unknown reasons, but probably was due to thunderstorms in the area. The pump was down for approximately 4 hr. The pump test was initiated at full vacuum (19"Hg). After 5 hours, the vacuum was cut to 16"Hg and



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Figure 3. Drop Tube Placement and Valve Position During the Skimmer Pump Test

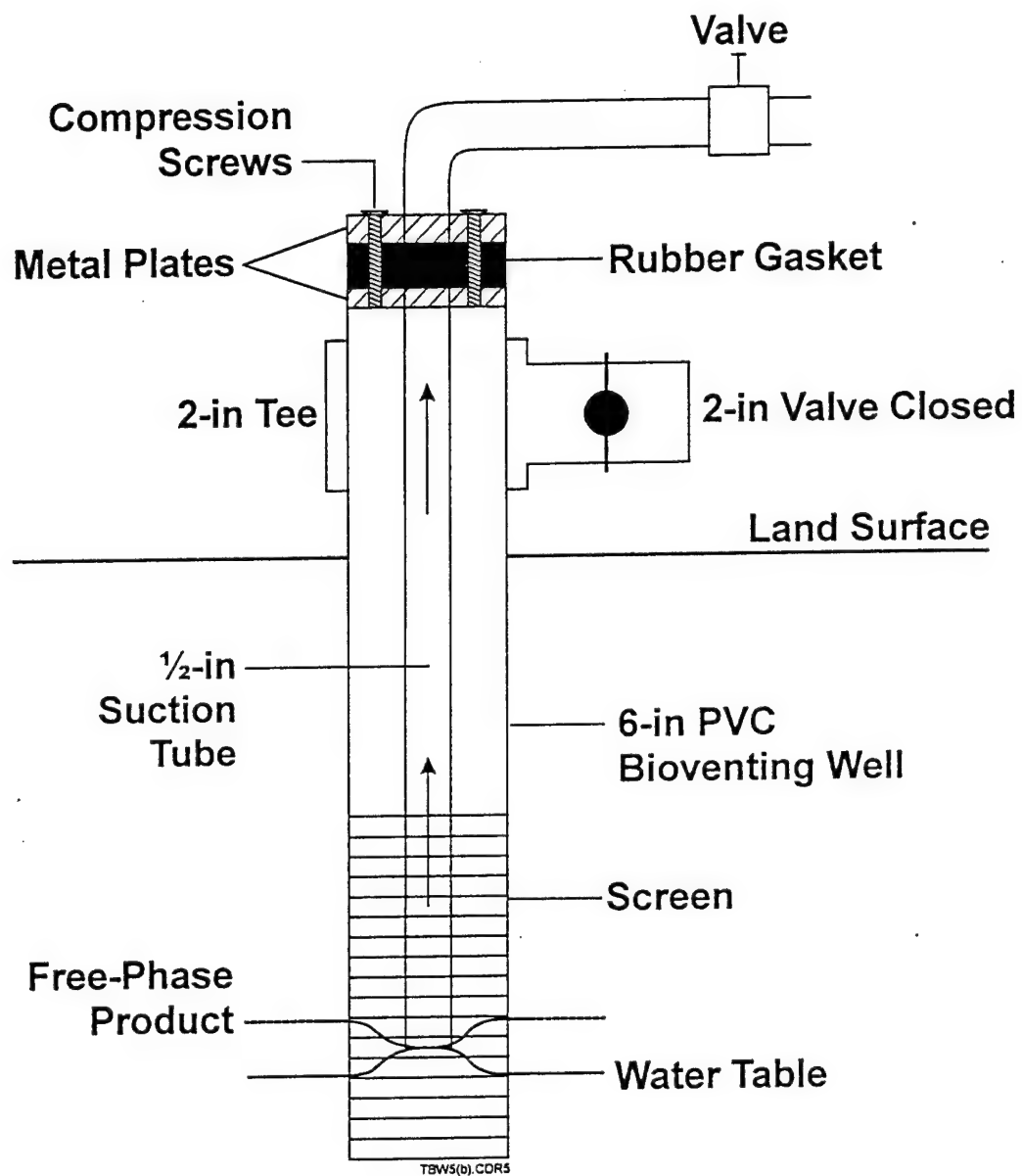


Figure 4. Drop Tube Placement and Valve Position During the Bioslurper Pump Test

after an additional 47.5 hr the pump was operated at full vacuum again (18"Hg). Vapor flowrates were approximately 9.5 scfm during the initial full vacuum portion of the pump test, 9.4 to 15 scfm during the reduced vacuum portion, and 14 to 26 scfm during the final full vacuum test. Well vacuums were approximately 26"H₂O during the initial full vacuum portion of the pump test, 12 to 13.5"H₂O during the reduced vacuum portion, and 21 to 22"H₂O during the final full vacuum test. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. The data sheets are provided in Appendix D.

3.5.4 Second Skimmer Pump Test

Upon completion of the bioslurper pump test at monitoring well MW 644, preparations were made to begin the second skimmer pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. The bioslurper system was used to conduct this skimmer pump test. The slurper tube was set at the oil/water interface. The drop tube was held in position by the well seal, and was positioned to leave the wellhead vented to the atmosphere. The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started at 4:15 pm, 15 July 1996, to begin the second skimmer pump test. The test was initiated approximately 0.5 hour after the bioslurper pump test and was operated continuously for 23 hours. The pump vacuum was approximately 15"Hg and the vapor flowrate was approximately 36 scfm. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

An LNAPL sample was collected from monitoring well MW 644 for analysis of BTEX and for boiling point fractionation and was labeled SHW-FP-1. The sample was sent to Alpha Analytical, Inc., in Sparks, Nevada for analysis.

3.5.5 Drawdown Pump Test

Upon completion of the second skimmer pump test, preparations were made to begin the drawdown pump test. Drawdown testing was conducted to determine if a cone of groundwater

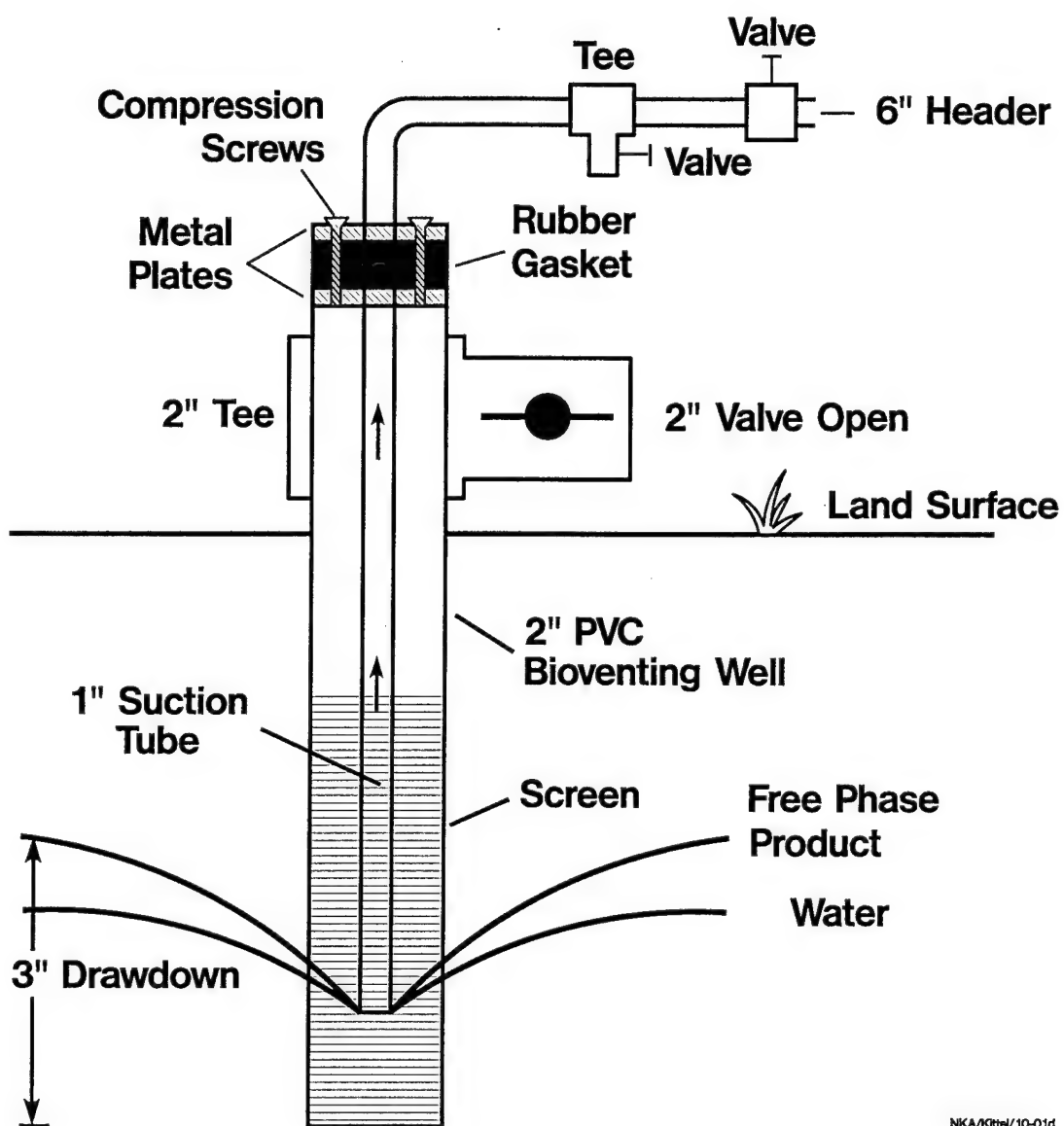
depression would enhance LNAPL recovery. The slurper tube was positioned 22 inches below the LNAPL/water interface measured prior to any recovery pump testing (Figure 5). The liquid ring pump was started at 8:10 am, 17 July 1996, to begin the drawdown pump test. The test was initiated approximately 17 hr after the second skimmer pump test was completed and was operated continuously for 28 hr. The pump vacuum was approximately 17"Hg and the vapor flowrate was approximately 26 scfm. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the drawdown pump test. Test data sheets are provided in Appendix D.

3.5.6 Off-Gas Sampling and Analysis

Three soil gas samples were collected during the pump tests at monitoring well MW 644. Samples SHW-AE-1 and SHW-AE-2 were collected during the bioslurper pump test at monitoring well MW 644 after 52 and 78 hr of operation, respectively. Sample SHW-AE-3 was collected during the second skimmer pump test following approximately 16 hr of operation. The samples were collected in Summa® canisters and sent under chain of custody to Air Toxics, Ltd., in Folsom, California, for analyses of BTEX and TPH, using EPA Method TO-3.

3.5.7 Groundwater Sampling and Analysis

Six groundwater samples were collected during the pump tests at monitoring well MW 644 and were labeled SHW-DC-1, SHW-DC-2, SHW-DC-3, SHW-DC-4, SHW-DC-5, and SHW-DC-6. Each sample was collected from the settling tank. Samples SHW-DC-1, SHW-DC-2, SHW-DC-3, and SHW-DC-4 were collected during the bioslurper pump test after approximately 52, 52, 78, and 78 hr of operation, respectively. Samples SHW-DC-5 and SHW-DC-6 were collected during the second skimmer pump test after approximately 16 hr of operation. Samples were collected in 40-mL septa vials containing hydrochloric acid (HC1) preservative. Samples were checked to ensure no headspace was present and were then shipped on ice and sent under chain of custody to Alpha Analytical, Inc., in Sparks, Nevada for analyses of BTEX and TPH (purgeable).



NKA/KRtel/10-01d

Figure 5. Drop Tube Placement and Valve Position for the Drawdown Pump Test

3.6 Bioventing Analyses

3.6.1 Soil Gas Permeability Testing

The soil gas permeability test data were collected during the bioslurper pump test at monitoring well MW 644. Before a vacuum was established in the extraction well, the initial soil gas pressures at the three installed monitoring points were recorded. The start of the bioslurper pump test created a steep pressure drop in the extraction well which was the starting point for the soil gas permeability testing. Soil gas pressures were measured at each of the three monitoring points at all depths to track the rate of outward propagation of the pressure drop in the extraction well. Soil gas pressure data were collected frequently during the first 20 minutes of the test. The soil gas pressures were recorded throughout the bioslurper pump test to determine the bioventing radius of influence. Test data are provided in Appendix E.

3.6.2 In Situ Respiration Testing

Air containing approximately 2% helium was injected into four monitoring points for approximately 21 hr beginning on 17 July 1996. The setup for the in situ respiration test is described in the Test Plan and Technical Protocol a Field Treatability Test for Bioventing (Hinchee et al., 1992). A ½-hp diaphragm pump was used for air and helium injection. Air and helium were injected through monitoring points SHW-MPA-30.0', SHW-MPA-35.0', SHW-MPA-40.0', and SHW-MPD-16.0'. After the air/helium injection was terminated, soil gas concentrations of oxygen, carbon dioxide, TPH, and helium were monitored periodically. The in situ respiration test was terminated on 18 July 1996. Oxygen utilization and biodegradation rates were calculated as described in Hinchee et al. (1992). Raw data for these tests are presented in Appendix F.

Helium concentrations were measured during the in situ respiration test to quantify helium leakage to or from the surface around the monitoring points. Helium loss over time is attributable to either diffusion through the soil or leakage. A rapid drop in helium concentration usually indicates leakage. A gradual loss of helium along with a first-order curve generally indicates diffusion. As a rough estimate, the diffusion of gas molecules is inversely proportional to the square root of the molecular weight of the gas. Based on molecular weights of 4 for helium and 32 for oxygen, helium diffuses approximately 2.8 times faster than oxygen, or the diffusion of oxygen is 0.35 times the rate

of helium diffusion. As a general rule, we have found that if helium concentrations at test completion are at least 50 to 60% of the initial levels, measured oxygen uptake rates are representative. Greater helium loss indicates a problem, and oxygen utilization rates are not considered representative.

4.0 RESULTS

This section documents the results of the site characterization, the comparative LNAPL recovery pump test, and other supporting tests conducted at Shaw AFB.

4.1 Baildown Test Results

Results from the baildown tests are presented in Tables 2 and 3. Baildown recovery tests provide a qualitative indication of the presence of mobile, free-phase LNAPL and recovery potential. Overall, the baildown recovery tests indicated a relatively high rate of LNAPL recovery into the wells. At monitoring well MW 644, LNAPL recovered to within 70% of initial levels by the end of the 4 hr baildown test. At monitoring well MW 634, LNAPL recovered to a level approximately 50% of the initial LNAPL thickness. Based on these results, pilot testing was initiated on monitoring well MW 644.

4.2 Soil Sample Analyses

Table 4 shows the TPH and BTEX concentrations measured in soil samples collected from Site SS-15. TPH and BTEX concentrations were very similar between samples with benzene below detection limits in both samples. TPH and BTEX concentrations averaged 385 mg/kg and 2.7 mg/kg, respectively. The results of the physical characterization and inorganic analysis of the soil are presented in Table 5. Soils were very permeable, with soils consisting primarily of sand.

Table 2. Baildown Test Results at Monitoring Well MW 634

| Sample Collection Time | Depth to Groundwater (ft) | Depth to LNAPL (ft) | LNAPL Thickness (ft) |
|--------------------------------|----------------------------------|----------------------------|-----------------------------|
| Initial Reading 7/8/96-1330 | | | 6.51 |
| 7/8/96-1358 | 51.36 | 50.71 | 0.65 |
| 7/8/96-1400 | 51.15 | 50.29 | 0.86 |
| 7/8/96-1402 | 50.89 | 49.81 | 1.08 |
| 7/8/96-1406 | 50.28 | 49.21 | 1.07 |
| 7/8/96-1409 | 50.01 | 48.99 | 1.02 |
| 7/8/96-1411 | 49.82 | 48.89 | 0.93 |
| 7/8/96-1414 | 49.45 | 48.63 | 0.82 |
| 7/8/96-1418 | 49.29 | 48.44 | 0.85 |
| 7/8/96-1422 | 49.16 | 48.21 | 0.95 |
| 7/8/96-1426 | 49.02 | 48.01 | 1.01 |
| 7/8/96-1431 | 48.88 | 47.79 | 1.09 |
| 7/8/96-1436 | 48.81 | 47.59 | 1.22 |
| 7/8/96-1441 | 48.77 | 47.31 | 1.46 |
| 7/8/96-1514 | 48.75 | 46.76 | 1.99 |
| 7/8/96-1549 | 48.81 | 46.41 | 2.40 |
| 7/8/96-1822 | 49.46 | 45.85 | 3.61 |

Table 3. Baildown Test Results at Monitoring Well MW 644

| Sample Collection Time | Depth to Groundwater (ft) | Depth to LNAPL (ft) | LNAPL Thickness (ft) |
|--------------------------------|----------------------------------|----------------------------|-----------------------------|
| Initial Reading 7/8/96-1430 | | | 4.34 |
| 7/8/96-1452 | 47.62 | 45.89 | 1.73 |
| 7/8/96-1454 | 47.55 | 45.81 | 1.74 |
| 7/8/96-1455 | 47.52 | 45.75 | 1.77 |
| 7/8/96-1456 | 47.42 | 45.65 | 1.77 |
| 7/8/96-1459 | 47.34 | 45.57 | 1.77 |
| 7/8/96-1502 | 47.25 | 45.43 | 1.82 |
| 7/8/96-1513 | 47.00 | 45.07 | 1.93 |
| 7/8/96-1518 | 46.95 | 44.96 | 1.99 |
| 7/8/96-1529 | 46.83 | 44.78 | 2.05 |
| 7/8/96-1601 | 46.81 | 44.46 | 2.35 |
| 7/8/96-1811 | 47.24 | 44.09 | 3.15 |

Table 4. TPH and BTEX Concentrations in Soil Samples

| Parameter | Concentration (mg/kg) | |
|-----------------|-----------------------|---------|
| | SHW-S-1 | SHW-S-2 |
| TPH (Purgeable) | 390 | 380 |
| Benzene | <0.10 | <0.10 |
| Toluene | 0.13 | 0.16 |
| Ethylbenzene | 0.28 | 0.33 |
| Total Xylenes | 1.8 | 2.5 |

Table 5. Physical Characterization of Soil Samples

| Parameter | | Sample | |
|------------------------------|------|---------|---------|
| | | SHW-S-1 | SHW-S-2 |
| Moisture Content (%) | | 1.8 | 2.3 |
| Porosity (%) | | 42.7 | 46.4 |
| Density (g/cm ³) | | 1.52 | 1.42 |
| Particle Size | Sand | 98.1 | NA |
| | Silt | 1.9 | NA |
| | Clay | 0 | NA |

4.3 LNAPL Pump Test Results

4.3.1 Initial Skimmer Pump Test Results

A significant quantity of LNAPL was recovered during this test during 48 hr of continuous extraction during the skimmer pump test (Table 6). The initial LNAPL recovery rate was 23.5 gallons/day, which dropped to 14.5 gallons/day by the second day of testing. A total of approximately 390 gallons of groundwater was produced with an average production rate of 196 gallons/day. Results of LNAPL recovery versus time are shown in Figure 6.

4.3.2 Bioslurper Pump Test Results

LNAPL recovery was significantly greater than that observed during the skimmer pump test (Figure 6). Bioslurper testing was conducted for approximately four days, resulting in relatively high recovery on the first day (46 gallons/day), with a significant reduction in recovery by day 2 to 28 gallons/day. However, by day 3, LNAPL recovery rates increased to 37 gallons/day, and remained relatively constant for the remainder of the testing. This increase on day 3 corresponds to increasing the pump vacuum and a corresponding increase in vapor flowrate and well vacuum.

A total of 150 gallons of LNAPL and 1,240 gallons of groundwater was extracted, with daily average recovery rates of 38 gallons/day for LNAPL and 320 gallons/day for groundwater (Table 6). The LNAPL recovery rate versus time is shown in Figure 7.

Soil gas concentrations were measured during the bioslurper test at monitoring points adjacent to monitoring well MW 644 to determine if the vadose zone was being oxygenated via the bioslurper action. Unfortunately, results were inconclusive based on oxygen measurements, although soil gas permeability testing indicated that a radius of influence of approximately 40 ft could be achieved. In general, it is our experience that oxygenation will occur at monitoring points where a perceptible pressure change is measured.

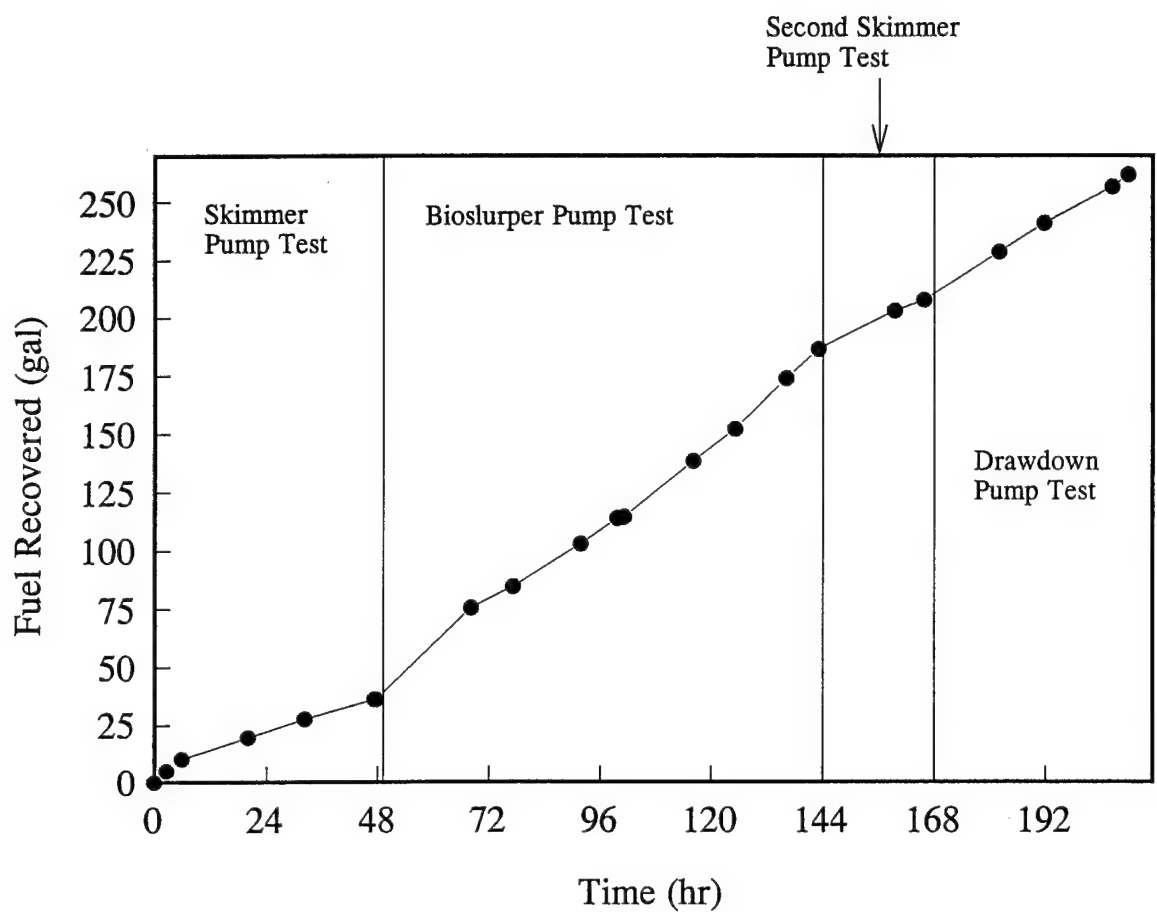
4.3.3 Second Skimmer Pump Test

LNAPL recovery rates during the second skimmer pump test were similar to the initial skimmer pump test during approximately 23 hours of continuous pumping. Approximately 21 gallons

Table 6. Pump Test Results at Monitoring Well MW 644

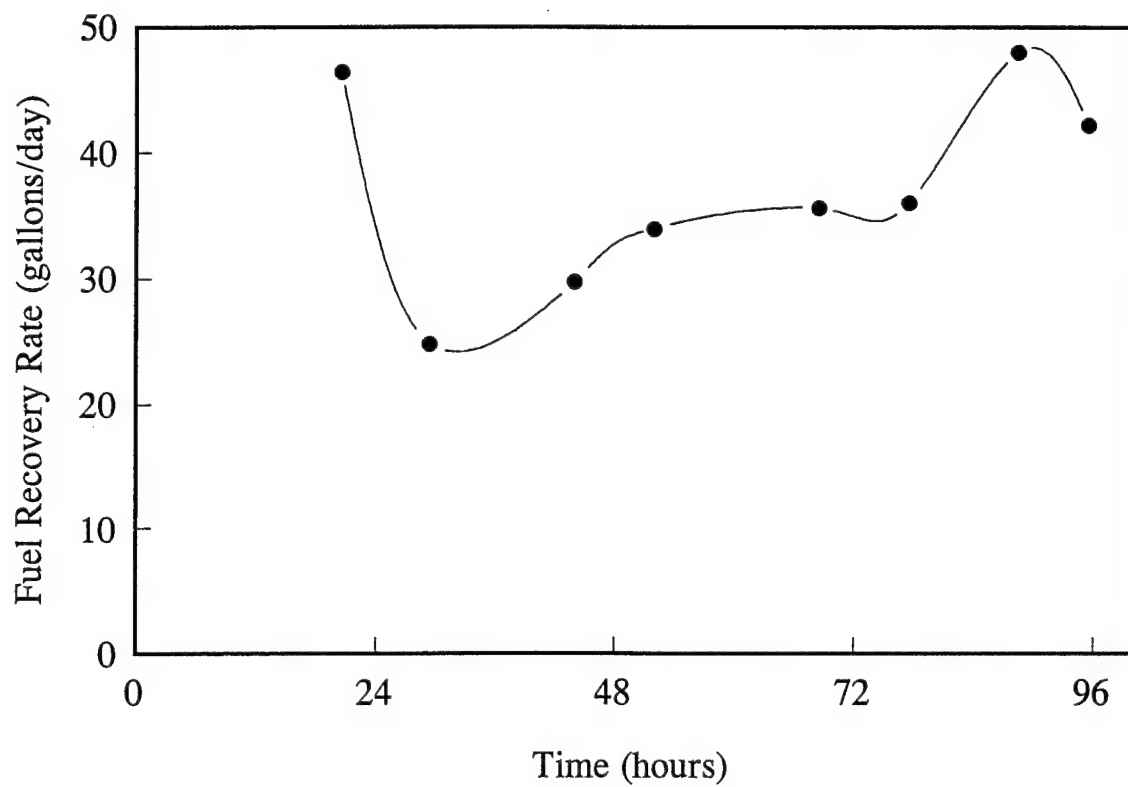
| Time (Days) | Recovery Rate (gallons/day) | | | | | | | |
|--------------------------------|------------------------------|-------------|----------------------|-------------|-----------------------------|-------------|--------------------|-------------|
| | Initial Skimmer Pump Test | | Bioslurper Pump Test | | Second Skimmer Pump Test | | Drawdown Pump Test | |
| | LNAPL | Groundwater | LNAPL | Groundwater | LNAPL | Groundwater | LNAPL | Groundwater |
| 1 | 24 | 180 | 46 | 320 | 22 | 190 | 31 | 240 |
| 2 | 15 | 210 | 28 | 240 | NA | NA | 28 | 230 |
| 3 | NA | NA | 37 | 350 | NA | NA | NA | NA |
| 4 | NA | NA | 36 | 250 | NA | NA | NA | NA |
| 5 | NA | NA | 42 | 340 | NA | NA | NA | NA |
| Average | 18 | 200 | 38 | 320 | 22 | 190 | 30 | 240 |
| Total Recovery (gallons) | 36.1 | 390 | 150 | 1,240 | 21.2 | 180 | 54.2 | 435 |

NA = Not applicable.



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Figure 6. LNAPL Recovery Versus Time During Each Pump Test



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Figure 7. LNAPL Recovery Rate Versus Time During the Bioslurper Pump Test

of LNAPL and 180 gallons of groundwater were recovered during the second skimmer pump test, with daily average recovery rates of 22 and 190 gallons/day, respectively (Table 6). These results demonstrate that operation of the bioslurper system in the skimmer mode was an effective means of free-product recovery, although recovery rates are significantly lower than during bioslurping.

4.3.4 Drawdown Pump Test

Drawdown pump testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed 22 inches below the static water table in monitoring well MW 644. Significant quantities of LNAPL were recovered, with average rates of 30 gallons/day and a total recovery of approximately 54 gallons (Table 6). Groundwater production rates were on the order of 240 gallons/day, with a total of approximately 440 gallons produced. These results demonstrate that the vacuum gradient maintained during the bioslurper test resulted in higher fluid recovery rates than the 22 inch-groundwater drawdown test.

4.3.5 Extracted Groundwater, LNAPL, and Off-Gas Analyses

Results of groundwater analyses are shown in Table 7. Contaminant concentrations were similar between the samples, with average TPH and total BTEX concentrations of 2.7 mg/L and 1.1 mg/L, respectively. The on-site water treatment equipment, consisting of a filter tank, oil/water separator, and clarification tanks, resulted in water effluent (2.3 to 3.0 mg/L total hydrocarbons) that is considered compatible with typical sanitary sewer discharge limits.

The results from the off-gas analyses are presented in Table 8. Given a flowrate of 12.5 scfm and using an average concentration of 12,500 ppmv TPH and 1,300 ppmv benzene, approximately 65 lb/day of TPH and 4.7 lb/day of benzene were emitted to the air. Thus, mass removal in the vapor phase is significant. Higher vapor mass removal rates are more often sustained at those sites where liquid product recovery is sustained. Sample SHW-AE-3 was collected during the second skimmer pump test and contaminant concentrations were approximately an order of magnitude higher than previously collected samples. There is no apparent reason for this difference, but may have been caused by a contaminant slug in the sample.

Table 7. BTEX and TPH Concentrations in Extracted Groundwater During Pump Tests

| Parameter | Concentration (mg/L) | | |
|-----------------|-------------------------|-------------------------|-------------------------|
| | SHW-DC-1/2 ¹ | SHW-DC-3/4 ¹ | SHW-DC-5/6 ¹ |
| TPH (purgeable) | 3.0 | 2.9 | 2.3 |
| Benzene | 0.062 | 0.076 | 0.11 |
| Toluene | 0.31 | 0.30 | 0.32 |
| Ethylbenzene | 0.11 | 0.097 | 0.10 |
| Total Xylenes | 0.64 | 0.61 | 0.63 |

¹ Samples SHW-DC-1, -3, and -6 were analyzed for BTEX only. Samples SHW-DC-2, -4, and -6 were analyzed for TPH only.

Collected from 1500 gal Tank

Table 8. BTEX and TPH Concentrations in Off-Gas During the Bioslurper Pump Test

| Parameter | Concentration (ppmv) | | |
|-----------------|----------------------|----------|-----------------------|
| | SHW-AE-1 | SHW-AE-2 | SHW-AE-3 ¹ |
| TPH as jet fuel | 13,000 | 12,000 | 130,000 |
| Benzene | 1,900 | 700 | 11,000 |
| Toluene | 1,900 | 1,100 | 14,000 |
| Ethylbenzene | 1,200 | 590 | 9,800 |
| Total Xylenes | 2,400 | 1,200 | 20,000 |

¹ Off-gas sample was not collected during bioslurper operations.

skimmer

The composition of LNAPL is shown in Tables 9 and 10 in terms of BTEX concentrations and distribution of C-range compounds, respectively. The distribution of C-range compounds also is shown graphically in Figure 8.

4.4 Bioventing Analyses

4.4.1 Soil Gas Permeability and Radius of Influence

The radius of influence is calculated by plotting the log of the pressure change at a specific monitoring point versus the distance from the extraction well. The radius of influence is then defined as the distance from the extraction well where 0.10 inch of H₂O can be measured. Based on this definition, the radius of influence during the bioslurper pump test at MW 644 was approximately 40 ft (Figure 9).

4.4.2 In Situ Respiration Test Results

Results from the in situ respiration test are presented in Table 11. Oxygen utilization rates were relatively high, ranging from 0.025 to 21 %O₂/hr. Biodegradation rates ranged from 0.41 to 340 mg/kg-day. Biodegradation rates were significantly higher at the deeper depths than at a depth of 16 ft bgl. These results indicate that biodegradation in these locations is significant and that bioventing is feasible at this site.

5.0 DISCUSSION AND CONCLUSIONS

The main objective of the field pilot test at Site SS-15, Shaw AFB was to determine if LNAPL recovery is feasible and to select the most effective method of LNAPL recovery.

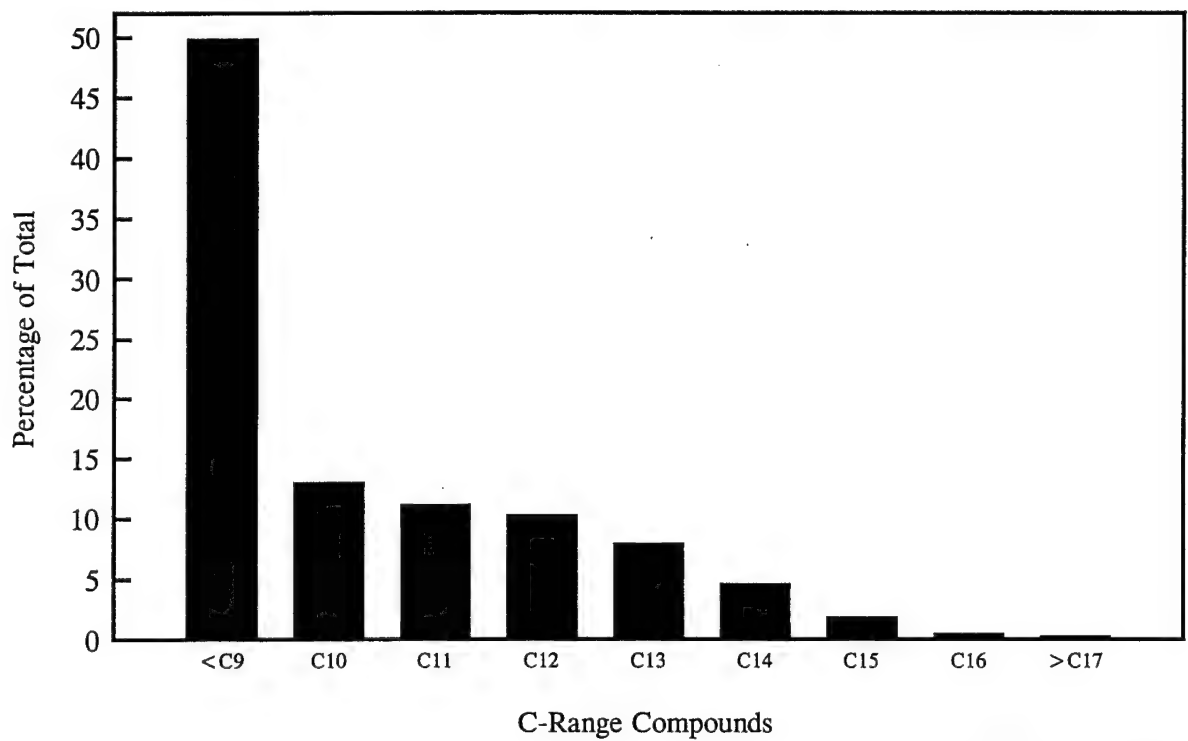
Baildown recovery tests were conducted at monitoring wells MW 634 and MW 644. Baildown recovery tests provide a qualitative indication of the presence of mobile, free-phase LNAPL and recovery potential. Overall, the baildown recovery tests indicated a relatively high rate of LNAPL recovery into the wells. At monitoring well MW 644, LNAPL recovered to within 70% of initial levels by the end of the 4 hr baildown test. At monitoring well MW 634, LNAPL recovered to

Table 9. BTEX Concentrations in LNAPL

| Compound | Concentration (mg/kg) |
|---------------|-----------------------|
| Benzene | 1,300 |
| Toluene | 7,100 |
| Ethylbenzene | 3,300 |
| Total Xylenes | 17,000 |

Table 10. C-Range Compounds in LNAPL

| C-Range | Percentage of Total (%) |
|---------|-------------------------|
| < C9 | 49.93 |
| C10 | 13.04 |
| C11 | 11.19 |
| C12 | 10.35 |
| C13 | 7.98 |
| C14 | 4.69 |
| C15 | 1.92 |
| C16 | 0.54 |
| > C17 | 0.36 |



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Figure 8. Distribution of C-Range Compounds in LNAPL

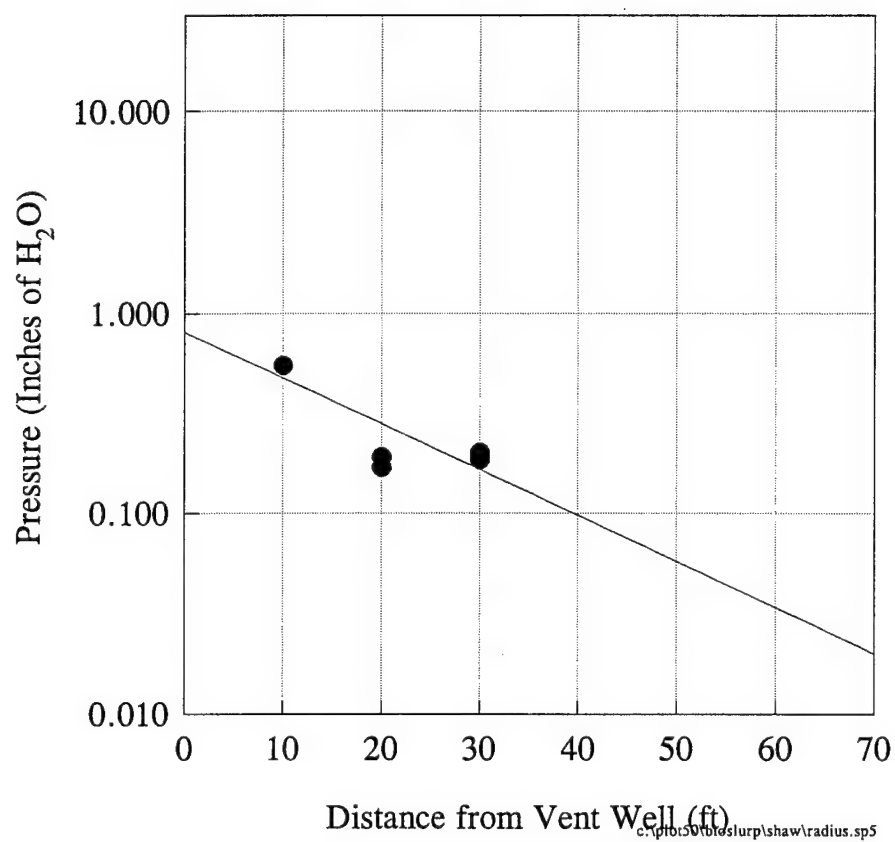


Figure 9. Radius of Influence Determination Using Soil Gas Pressure Change Versus Distance From Extraction Well

Table 11. In Situ Respiration Test Results

| Monitoring Point | Oxygen Utilization Rate (%/hr) | Biodegradation Rate (mg/kg-day) |
|-------------------------|---------------------------------------|----------------------------------------|
| MPA-30' | 2.4 | 39 |
| MPA-35' | 5.6 | 91 |
| MPA-40' | 21 | 340 |
| MPD-16' | 0.025 | 0.41 |

a level approximately 50% of the initial LNAPL thickness. Based on these results, pilot testing was initiated on monitoring well MW 644.

Direct pumping tests were conducted at monitoring well MW 644. Skimmer pump testing was conducted at monitoring well MW 644 in a continuous extraction mode for two days. A significant quantity of LNAPL was recovered during this pump test. The initial LNAPL recovery rate was 23.5 gallons/day, which dropped to 14.5 gallons/day by the second day of testing. A total of approximately 390 gallons of groundwater was produced with an average production rate of 200 gallons/day. LNAPL recovery was significantly greater during the bioslurper pump test than that observed during the skimmer pump test. Bioslurper testing was conducted for approximately four days, resulting in relatively high recovery on the first day (46 gallons/day), with a significant reduction in recovery by day 2 to 28 gallons/day. However, by day 3, LNAPL recovery rates increased to 37 gallons/day, and remained relatively constant for the remainder of the testing. This increase on day 3 corresponds to increasing the pump vacuum and a corresponding increase in vapor flowrate and well vacuum. A total of 150 gallons of LNAPL and 1,240 gallons of groundwater was extracted, with daily average recovery rates of 38 gallons/day for LNAPL and 320 gallons/day for groundwater.

LNAPL recovery rates during the second skimmer pump test were similar to the initial skimmer pump test during approximately 23 hours of continuous pumping. Approximately 21 gallons of LNAPL and 180 gallons of groundwater were recovered during the second skimmer pump test, with daily average recovery rates of 22 and 190 gallons/day, respectively. These results demonstrate that operation of the bioslurper system in the skimmer mode was an effective means of free-product recovery, although recovery rates are significantly lower than during bioslurping.

Drawdown pump testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed 22 inches below the static water table in monitoring well MW 644. Significant quantities of LNAPL were recovered, with average rates of 30 gallons/day and a total recovery of approximately 54 gallons. Groundwater production rates were on the order of 240 gallons/day, with a total of approximately 440 gallons produced. These results demonstrate that the vacuum gradient maintained during the bioslurper test resulted in higher fluid recovery rates than the 22 inch-groundwater drawdown test.

Bioslurping also promotes mass removal in the form of in situ biodegradation via bioventing and soil gas extraction. Vapor phase mass removal is the result of soil gas extraction as well as volatilization that occurs during the movement of LNAPL free product through the extraction network. Given a flowrate of 12.5 scfm and using an average concentration of 12,500 ppmv TPH and 1,300 ppmv benzene, approximately 65 lb/day of TPH and 4.7 lb/day of benzene were emitted to the air. Thus, mass removal in the vapor phase is significant. Higher vapor mass removal rates are more often sustained at those sites where liquid product recovery is sustained.

The initial soil gas profiles at the site displayed oxygen-deficient, carbon dioxide-rich, high total volatile hydrocarbon vapor conditions at depths from 30 to 40 ft bgl. These conditions indicate that natural biodegradation of residual petroleum hydrocarbons has occurred, but is limited by oxygen availability. Soil gas concentrations were measured during the bioslurper test at monitoring points adjacent to monitoring well MW 644 to determine if the vadose zone was being oxygenated via the bioslurper action. Unfortunately, results were inconclusive based on oxygen measurements, although soil gas permeability testing indicated that a radius of influence of approximately 40 ft could be achieved. In general, it is our experience that oxygenation will occur at monitoring points where a perceptible pressure change is measured. In situ biodegradation rates 0.025 to 21 mg/kg-day were measured at four different locations. Based on the radius of influence of 40 ft and a hydrocarbon-impacted soil thickness of 40 ft, mass removal rates via biodegradation are on the order of 0.43 to 370 lbs of hydrocarbon per day. Thus, mass removal rates via biodegradation could be more significant than the vapor phase removal rates measured during the bioslurper test. These results indicate that bioventing is feasible at this site. Air injection bioventing is preferable over bioslurping and soil vapor extraction with respect to the elimination of hydrocarbon vapor emissions.

In summary, the on-site testing at Site SS-15, Shaw AFB, included the direct testing of gravity-driven and vacuum-driven LNAPL free product recovery techniques, bioventing, physical sampling, and tests relevant to soil vapor extraction. Liquid phase recovery was sustainable during

all pump tests, with the highest recoveries during bioslurping. The in situ respiration test and vadose zone radius of influence testing demonstrate that bioventing may be feasible at this site. Bioslurping appears to be a suitable recovery technique for this site.

6.0 REFERENCES

Battelle, 1995. Test Plan and Technical Protocol for Bioslurping. Report prepared by Battelle Columbus Operations for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. 1992. Test Plan and Technical Protocol for a Field Treatability Test for Bioventing (Rev. 2). Report prepared by Battelle Columbus Operations, U.S. Air Force Center for Environmental Excellence, and Engineering Sciences, Inc., for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

APPENDIX A

**SITE-SPECIFIC TEST PLAN FOR BIOSLURPER FIELD ACTIVITIES
AT SHAW AFB, SOUTH CAROLINA**

**SITE-SPECIFIC TEST PLAN FOR BIOSLURPER TESTING AT
SHAW AIR FORCE BASE, SOUTH CAROLINA (A002)
CONTRACT NO. F41624-94-C-8012**

DRAFT

to

**U.S. Air Force
8001 Arnold Drive
Building 642
Brooks AFB, TX 78235**

May 3, 1995

by

**Battelle
505 King Avenue
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CONTENTS

| | | |
|-------|----------------------------------------------------------|----|
| 1.0 | INTRODUCTION | 1 |
| 2.0 | SITE DESCRIPTION | 2 |
| 3.0 | PROJECT ACTIVITIES | 2 |
| 3.1 | Mobilization to the Site | 2 |
| 3.2 | Site Characterization Tests | 6 |
| 3.2.1 | Baildown Tests | 6 |
| 3.2.2 | Soil-Gas Survey (Limited) | 7 |
| 3.2.3 | Slug Tests | 7 |
| 3.2.4 | Monitoring Point Installation | 10 |
| 3.3 | Bioslurper System Installation and Operation | 11 |
| 3.3.1 | System Setup | 11 |
| 3.3.2 | System Shakedown | 13 |
| 3.3.3 | System Startup and Test Operations | 13 |
| 3.3.4 | Soil-Gas Permeability Tests | 13 |
| 3.3.5 | In Situ Respiration Tests | 13 |
| 3.3.6 | Extended Testing | 14 |
| 3.4 | Demobilization | 14 |
| 4.0 | BIOSLURPER SYSTEM DISCHARGE | 14 |
| 4.1 | Vapor Discharge Disposition | 14 |
| 4.2 | Aqueous Influent/Effluent Disposition | 16 |
| 4.3 | Free-Product Recovery Disposition | 16 |
| 5.0 | SCHEDULE | 17 |
| 6.0 | PROJECT SUPPORT ROLES | 17 |
| 6.1 | Battelle Activities | 17 |
| 6.2 | Shaw AFB Support Activities | 17 |
| 6.3 | AFCEE Activities | 20 |
| | APPENDIX A. WELL CONSTRUCTION AND SOIL BORING LOGS | 21 |

FIGURES

| | | |
|-----------|-------------------------------------------------------------------------|----|
| Figure 1. | Location of Areas of Interest for Bioslurper Testing at Shaw AFB | 3 |
| Figure 2. | General Bioslurper Well and Monitoring Point Arrangement | 8 |
| Figure 3. | Diagram of a Typical Bioslurper Soil-Gas Monitoring Point | 9 |
| Figure 4. | Conceptual Arrangement for Soil-Gas Monitoring Points at UST Area | 10 |
| Figure 5. | Bioslurper Process Flow | 11 |
| Figure 6. | Diagram of a Typical Bioslurper Well | 12 |

CONTENTS (Continued)

TABLES

| | |
|--------------------------------------------------------------------------------------|----|
| Table 1. Subsurface Apparent Fuel Thickness for Wells in or Near the POL Depot | 4 |
| Table 2. Schedule of Bioslurper Test Activities | 6 |
| Table 3. Volumes Per Unit Length for Common Well Casing Diameters | 7 |
| Table 4. Benzene and TPH Discharge Levels at Previous Bioslurper Test Sites | 15 |
| Table 5. Air Release Summary Information | 16 |
| Table 6. Health and Safety Information Checklist | 19 |

**SITE-SPECIFIC TEST PLAN FOR BIOSLURPER FIELD ACTIVITIES AT
SHAW AIR FORCE BASE, SOUTH CAROLINA (A002)**

DRAFT

**U.S. Air Force
Brooks AFB**

May 3, 1995

1.0 INTRODUCTION

The Air Force Center for Environmental Excellence is conducting a nationwide application of an innovative technology for free-product recovery and soil bioremediation. The technology tested in the Bioslurper Initiative is vacuum-enhanced free-product recovery/bioremediation (bioslurping). The field test and evaluation are intended to demonstrate the initial feasibility of bioslurping by measuring system performance in the field. System performance parameters, mainly free-product recovery, will be determined at numerous sites. Field testing will be performed at many sites to determine the effects of different organic contaminant types and concentrations and different geological conditions on bioslurping effectiveness.

Plans for the field test activities are presented in two documents. The first is the overall test plan and technical protocol for the entire program, titled *Test Plan and Technical Protocol for Bioslurping* (Battelle, 1995). The overall plan is supplemented by plans specific to each test site. The concise site-specific plans effectively communicate regulatory background to Base personnel.

The overall test plan and protocol was developed as a generic plan for the Bioslurper Initiative to improve the accuracy and efficiency of test plan preparation. The field program requires installation and operation of the bioslurping system supported by a wide variety of site characterization, performance monitoring, and chemical analysis activities. The basic methods to be applied from site to site do not change. Preparation and review of the overall plan allows efficient documentation and review of the basic approach to the test program. Peer and regulatory review were performed for the overall plan to ensure the credibility of the overall program.

This letter report is the site-specific plan for application of bioslurping at Shaw Air Force Base, South Carolina. It was prepared based on site-specific information received by Battelle from Shaw AFB and other pertinent site-specific information to support the generic test plan.

Site-specific information for Shaw AFB included data for the POL Depot and surrounding area. An initial review of the data indicates that the southeastern corner of the depot is the most likely candidate for the bioslurper pilot test. Specifically, Well #COE-T22, near Building 103, and Well #MW-506, at the underground storage tank (UST) Site SS-15, appear to be good candidates for the bioslurper field test. If the southeastern corner of the POL site is found unsuitable for testing, the area south of the POL depot is a viable alternative.

2.0 SITE DESCRIPTION

The site of interest is the southeastern corner of the POL Depot. The organic liquid contaminant is JP-4 jet fuel, and the primary source of contamination appears to be the underground storage tank farms. Figure 1 shows the POL Depot site, including the monitoring wells in the vicinity and the extent of the free-product plume. Table 1 summarizes the subsurface fuel thickness measurement data for all wells located in the area around the POL Depot. From these data, the wells that are most likely to yield significant amounts of free product have been identified. Well #COE-T2 and Well #MW-506 had the greatest fuel thickness when measurements were taken January 16, 1992; their measurements were 3.14 and 2.62 ft, respectively. When the July 15, 1993, measurement was taken, these thicknesses had reduced to 1.88 and 1.65 ft, but were still the largest amounts of free product measured in the site wells. This decrease in fuel thickness most likely is the result of an interim free-product/groundwater recovery system that has been in operation since May 18, 1991.

Site characterization (see Section 3.2) will begin with the wells residing in the free-product plume (see Figure 1) within the POL Depot. If these wells prove unsuitable, or if site logistics prevent their use, the wells south of the POL Depot will be used. Possible candidate wells for the bioslurper pilot test are Well #MW-617 and Well #MW-634. Information on the well construction data of possible candidate wells is located in Appendix A.

The principal organic liquid contaminant in the candidate test site at Shaw AFB is JP-4 jet fuel. Previous analyses have shown that the principal constituents at the site are benzene, toluene, ethylbenzene, and xylenes (BTEX). The BTEX concentration in groundwater in the area of Well #COE-T2 and Well #MW-506 is approximately 5 ppm, with a benzene concentration of approximately 1.4 ppm.

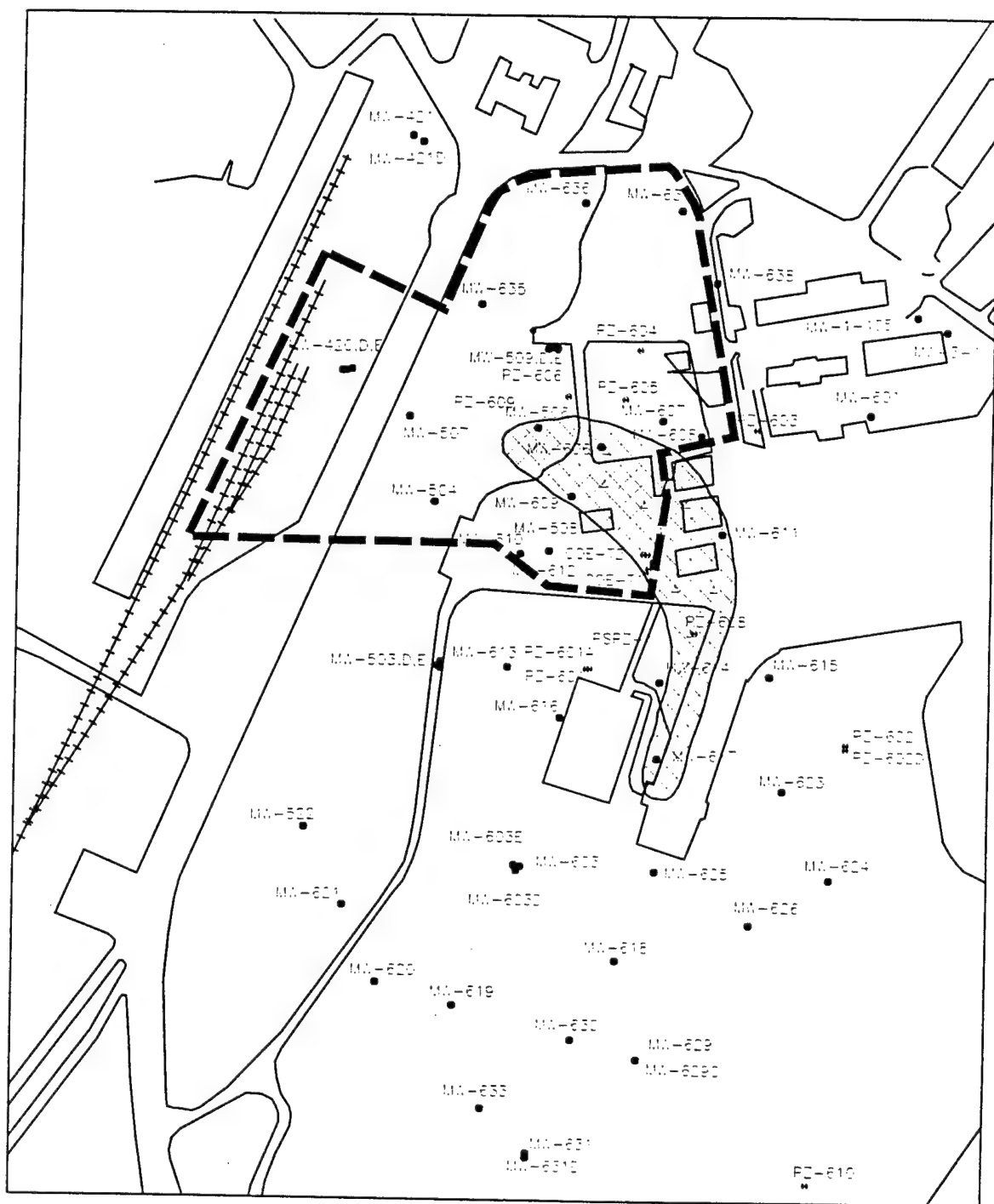
Polycyclic aromatic hydrocarbons (PAHs) also have been found to be present at the site. Previous analyses of the groundwater at the site have revealed the presence of four PAHs — acenaphthene, naphthalene, methylnaphthalene, and fluorene. However, all previous analyses of the site soils and groundwater have indicated that the main source of contamination at the site is the free-product plume of JP-4 jet fuel.

3.0 PROJECT ACTIVITIES

The following field activities are planned for the bioslurper pilot test at Shaw AFB. Additional details about the activities are presented in the *Test Plan and Technical Protocol for Bioslurping* (Battelle, 1995). As appropriate, specific sections in the generic Bioslurping Protocol assessment are referenced. Table 2 shows the schedule of activities for the Bioslurper Initiative at Shaw AFB.

3.1 Mobilization to the Site

After the site-specific test plan is approved, Battelle staff will mobilize equipment. All equipment will be mobilized to Shaw AFB by Battelle staff. The exact mobilization date will be confirmed with the Base Point of Contact (POC) as far in advance of fieldwork as is possible. The Battelle POC will provide the Base POC with information on each Battelle employee who will be on site.



Legend

- Piezometer
- Monitoring Well
- △ Recovery Well

- ⊠ Plume
- POL Depot

Scale
0 100 200 300
FEET

Figure 1. Location of Areas of Interest for Bioslurper Testing at Shaw AFB

Table 1. Subsurface Apparent Fuel Thickness for Wells in or Near the POL Depot.

| WELL ID | Easting (feet) | Northing (feet) | 12/16/92 | | | 02/02/93 | | | 04/06/93 | | | 06/04/93 | | | 7/15/93 | | |
|----------|-------------------|--------------------|------------------------------------|--------------------------------|-------|------------------------------------|--------------------------------|------|------------------------------------|--------------------------------|-------|------------------------------------|--------------------------------|------|------------------------------------|--------------------------------|--|
| | | | Water Level Elevation (feet) | Product Thickness (feet) | | Water Level Elevation (feet) | Product Thickness (feet) | | Water Level Elevation (feet) | Product Thickness (feet) | | Water Level Elevation (feet) | Product Thickness (feet) | | Water Level Elevation (feet) | Product Thickness (feet) | |
| COE-T1 | 2156293 | 351283 | 210.4 | 0.61 | 211.4 | 0.57 | 211.7 | 0.68 | 212.5 | 0.63 | 212.5 | 0.63 | 212.5 | 0.63 | 212.5 | 0.63 | |
| COE-T2 | 2156296 | 351321 | 210.5 | 1.88 | 211.3 | 1.70 | 210.6 | 2.03 | 213.2 | 3.14 | 213.2 | 3.14 | 213.2 | 3.14 | 213.2 | 3.14 | |
| COE-T3 | 2156288 | 351321 | 218.9 | 0.02 | 220.4 | 0.01 | 220.0 | 0.01 | 218.7 | 0.02 | 218.7 | 0.02 | 218.7 | 0.02 | 218.7 | 0.02 | |
| MW-1-105 | 2156863 | 351777 | 213.5 | 0.00 | 214.4 | 0.00 | 215.3 | 0.00 | 215.6 | 0.00 | 215.6 | 0.00 | 215.6 | 0.00 | 215.6 | 0.00 | |
| MW-2-105 | 2156843 | 351804 | 215.1 | 0.00 | 216.0 | 0.00 | 216.9 | 0.00 | 217.2 | 0.00 | 217.2 | 0.00 | 217.2 | 0.00 | 217.2 | 0.00 | |
| MW-3-105 | 2156904 | 351775 | 214.3 | 0.00 | 215.3 | 0.00 | 216.1 | 0.00 | 216.4 | 0.00 | 216.4 | 0.00 | 216.4 | 0.00 | 216.4 | 0.00 | |
| MW-420 | 2156673 | 351690 | 214.9 | 0.00 | 215.4 | 0.00 | 216.4 | 0.00 | 217.0 | 0.00 | 217.0 | 0.00 | 217.0 | 0.00 | 217.0 | 0.00 | |
| MW-420D | 2156666 | 351689 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| MW-420E | 2156684 | 351692 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| MW-421 | 2155800 | 352160 | 218.9 | 0.00 | 219.2 | 0.00 | 220.2 | 0.00 | 220.5 | 0.00 | 220.5 | 0.00 | 220.5 | 0.00 | 220.5 | 0.00 | |
| MW-421D | 2155821 | 352148 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| MW-501 | 2157985 | 349332 | 208.8 | 0.00 | 211.1 | 0.00 | 211.3 | 0.00 | 209.8 | 0.00 | 209.8 | 0.00 | 209.8 | 0.00 | 209.8 | 0.00 | |
| MW-502 | 2156862 | 348849 | 209.1 | 0.00 | 211.6 | 0.00 | 212.2 | 0.00 | 211.7 | 0.00 | 211.7 | 0.00 | 211.7 | 0.00 | 211.7 | 0.00 | |
| MW-503 | 2155866 | 351090 | 210.2 | 0.00 | 212.2 | 0.00 | 213.0 | 0.00 | 213.3 | 0.00 | 213.3 | 0.00 | 213.3 | 0.00 | 213.3 | 0.00 | |
| MW-503D | 2155871 | 351085 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| MW-503E | 2155872 | 351098 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| MW-504 | 2155855 | 351425 | 212.0 | 0.00 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| MW-505 | 2156309 | 351304 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| MW-506 | 2156197 | 351540 | 211.8 | 2.62 | 212.6 | 2.61 | 212.3 | 1.88 | 214.0 | 1.65 | 214.0 | 1.65 | 214.0 | 1.65 | 214.0 | 1.65 | |
| MW-507 | 2155802 | 351597 | 213.2 | 0.00 | 213.9 | 0.00 | 215.0 | 0.00 | 215.5 | 0.00 | 215.5 | 0.00 | 215.5 | 0.00 | 215.5 | 0.00 | |
| MW-508 | 2156092 | 351326 | 210.8 | 0.00 | 211.6 | 0.00 | 212.7 | 0.00 | 213.1 | 0.00 | 213.1 | 0.00 | 213.1 | 0.00 | 213.1 | 0.00 | |
| MW-509 | 2156104 | 351736 | 213.4 | 0.00 | 214.0 | 0.00 | 215.2 | 0.00 | 215.6 | 0.00 | 215.6 | 0.00 | 215.6 | 0.00 | 215.6 | 0.00 | |
| MW-509D | 2156095 | 351738 | 174.5 | 0.00 | 174.9 | 0.00 | 176.5 | 0.00 | 176.1 | 0.00 | 176.1 | 0.00 | 176.1 | 0.00 | 176.1 | 0.00 | |
| MW-509E | 2156085 | 351736 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| MW-601 | 2156750 | 351606 | 212.7 | 0.00 | 213.5 | 0.00 | 173.3 | 0.00 | 172.0 | 0.00 | 172.0 | 0.00 | 172.0 | 0.00 | 172.0 | 0.00 | |
| MW-602 | 2157378 | 351448 | 213.8 | 0.00 | 215.0 | 0.00 | 214.5 | 0.00 | 214.8 | 0.00 | 214.8 | 0.00 | 214.8 | 0.00 | 214.8 | 0.00 | |
| MW-603 | 2156042 | 350681 | 206.6 | 0.00 | 207.9 | 0.00 | 216.2 | 0.00 | 216.3 | 0.00 | 216.3 | 0.00 | 216.3 | 0.00 | 216.3 | 0.00 | |
| MW-603D | 2156028 | 350684 | 183.2 | 0.00 | 183.9 | 0.00 | 209.4 | 0.00 | 209.9 | 0.00 | 209.9 | 0.00 | 209.9 | 0.00 | 209.9 | 0.00 | |
| MW-603E | 2156033 | 350672 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| MW-604 | 2157431 | 350216 | 208.3 | 0.00 | 210.4 | 0.00 | 174.5 | 0.00 | 185.3 | 0.00 | 185.3 | 0.00 | 185.3 | 0.00 | 185.3 | 0.00 | |
| MW-605 | 2159983 | 350133 | 206.6 | 0.00 | 209.2 | 0.00 | 211.1 | 0.00 | 173.0 | 0.00 | 173.0 | 0.00 | 173.0 | 0.00 | 173.0 | 0.00 | |
| MW-606 | 2156066 | 351576 | 212.4 | 0.00 | 212.1 | 0.00 | 209.5 | 0.00 | 212.3 | 0.00 | 212.3 | 0.00 | 212.3 | 0.00 | 212.3 | 0.00 | |
| MW-607 | 2156324 | 351592 | 212.0 | 2.50 | 212.8 | 2.48 | 214.2 | 0.00 | 208.6 | 0.00 | 208.6 | 0.00 | 208.6 | 0.00 | 208.6 | 0.00 | |
| MW-608 | 2156404 | 351561 | 211.8 | 1.50 | 211.5 | 1.44 | 211.2 | 3.27 | 214.6 | 0.00 | 214.6 | 0.00 | 214.6 | 0.00 | 214.6 | 0.00 | |
| MW-609 | 2156138 | 351438 | 211.3 | 0.00 | 212.3 | 0.00 | 212.7 | 1.15 | 211.4 | 0.00 | 211.4 | 0.00 | 211.4 | 0.00 | 211.4 | 0.00 | |
| MW-610 | 2156032 | 351320 | 211.1 | 0.00 | 211.8 | 0.00 | 213.2 | 0.00 | 213.3 | 0.00 | 213.3 | 0.00 | 213.3 | 0.00 | 213.3 | 0.00 | |
| MW-611 | 2156451 | 351363 | 210.6 | 1.52 | 211.5 | 1.04 | 212.9 | 0.02 | 212.3 | 0.00 | 212.3 | 0.00 | 212.3 | 0.00 | 212.3 | 0.00 | |
| MW-612 | 2156113 | 351255 | 210.0 | 0.00 | 210.7 | 0.00 | 211.5 | 0.34 | 212.0 | 0.34 | 212.0 | 0.34 | 212.0 | 0.34 | 212.0 | 0.34 | |
| MW-613 | 2156009 | 351088 | 209.1 | 0.00 | 210.0 | 0.00 | 211.8 | 0.00 | 212.2 | 0.00 | 212.2 | 0.00 | 212.2 | 0.00 | 212.2 | 0.00 | |
| MW-614 | 2156325 | 351060 | 208.6 | 0.00 | 209.7 | 0.00 | 211.3 | 0.00 | 211.6 | 0.00 | 211.6 | 0.00 | 211.6 | 0.00 | 211.6 | 0.00 | |
| MW-615 | 2156551 | 351072 | 209.7 | 0.00 | 210.7 | 0.00 | 210.8 | 0.00 | 210.6 | 0.00 | 210.6 | 0.00 | 210.6 | 0.00 | 210.6 | 0.00 | |
| MW-616 | 2156119 | 350986 | 207.8 | 0.01 | 208.9 | 0.00 | 211.7 | 0.00 | 211.8 | 0.00 | 211.8 | 0.00 | 211.8 | 0.00 | 211.8 | 0.00 | |
| MW-617 | 2156322 | 350904 | 207.1 | 1.63 | 208.2 | 1.25 | 210.3 | 0.00 | 210.4 | 0.00 | 210.4 | 0.00 | 210.4 | 0.00 | 210.4 | 0.00 | |
| MW-618 | 2156241 | 350490 | 205.7 | 0.00 | 207.1 | 0.00 | 208.4 | 1.01 | 209.5 | 0.97 | 209.5 | 0.97 | 209.5 | 0.97 | 209.5 | 0.97 | |
| MW-619 | 2155906 | 350396 | 206.4 | 0.00 | 207.7 | 0.00 | 208.6 | 0.00 | 209.0 | 0.00 | 209.0 | 0.00 | 209.0 | 0.00 | 209.0 | 0.00 | |
| MW-620 | 2155749 | 350441 | 207.0 | 0.00 | 208.2 | 0.00 | 209.3 | 0.00 | 209.7 | 0.00 | 209.7 | 0.00 | 209.7 | 0.00 | 209.7 | 0.00 | |
| MW-621 | 2155680 | 350598 | --- | --- | 209.1 | 0.00 | 210.8 | 0.00 | 210.3 | 0.00 | 210.3 | 0.00 | 210.3 | 0.00 | 210.3 | 0.00 | |
| MW-622 | 2155600 | 350757 | 209.0 | 0.00 | 209.9 | 0.00 | 211.7 | 0.00 | 211.4 | 0.00 | 211.4 | 0.00 | 211.4 | 0.00 | 211.4 | 0.00 | |
| MW-623 | 2156580 | 350838 | --- | --- | 208.3 | 0.00 | 209.5 | 0.00 | 212.4 | 0.00 | 212.4 | 0.00 | 212.4 | 0.00 | 212.4 | 0.00 | |
| MW-624 | 2156678 | 350657 | --- | --- | 208.0 | 0.00 | 209.3 | 0.00 | 209.7 | 0.00 | 209.7 | 0.00 | 209.7 | 0.00 | 209.7 | 0.00 | |

Table 1. Subsurface Apparent Fuel Thickness for Wells in or Near the POL Depot. (Continued)

| WELL ID | Easting (feet) | Northing (feet) | 12/16/92 | | | 02/02/93 | | | 04/06/93 | | | 06/04/93 | | | 7/15/93 | | |
|---------|-------------------|--------------------|------------------------------------|--------------------------------|-------|------------------------------------|--------------------------------|------|------------------------------------|--------------------------------|-------|------------------------------------|--------------------------------|------|------------------------------------|--------------------------------|--|
| | | | Water Level Elevation (feet) | Product Thickness (feet) | | Water Level Elevation (feet) | Product Thickness (feet) | | Water Level Elevation (feet) | Product Thickness (feet) | | Water Level Elevation (feet) | Product Thickness (feet) | | Water Level Elevation (feet) | Product Thickness (feet) | |
| MW-625 | 2156320 | 350672 | 205.8 | 0.00 | 207.1 | 0.01 | 208.5 | 0.00 | 208.9 | 0.00 | 208.9 | 0.00 | 208.9 | 0.00 | 208.9 | 0.00 | |
| MW-626 | 2156516 | 350564 | 248.1 | 0.00 | 207.3 | 0.00 | 208.7 | 0.00 | 208.9 | 0.00 | 208.9 | 0.00 | 208.9 | 0.00 | 208.9 | 0.00 | |
| MW-627 | 2155714 | 349785 | --- | --- | --- | 0.01 | 205.8 | 0.00 | 207.4 | 0.00 | 207.4 | 0.00 | 207.4 | 0.00 | 207.4 | 0.00 | |
| MW-628 | 2155965 | 349670 | --- | --- | --- | --- | 207.9 | 0.00 | 208.3 | 0.00 | 208.3 | 0.00 | 208.3 | 0.00 | 208.3 | 0.00 | |
| MW-629 | 2156288 | 350287 | --- | --- | 206.7 | 0.00 | 208.2 | 0.00 | 208.5 | 0.00 | 208.5 | 0.00 | 208.5 | 0.00 | 208.5 | 0.00 | |
| MW-630 | 2156152 | 350327 | --- | --- | 206.9 | 0.00 | 208.5 | 0.00 | 208.8 | 0.00 | 208.8 | 0.00 | 208.8 | 0.00 | 208.8 | 0.00 | |
| MW-631 | 2156062 | 350087 | --- | --- | 206.2 | 0.00 | 208.0 | 0.00 | 208.4 | 0.00 | 208.4 | 0.00 | 208.4 | 0.00 | 208.4 | 0.00 | |
| MW-632 | 2155394 | 349581 | --- | --- | 201.7 | 0.00 | 203.6 | 0.00 | 204.2 | 0.00 | 204.2 | 0.00 | 204.2 | 0.00 | 204.2 | 0.00 | |
| MW-633 | 2155967 | 350185 | --- | --- | 207.0 | 0.00 | 208.6 | 0.00 | 209.0 | 0.00 | 209.0 | 0.00 | 209.0 | 0.00 | 209.0 | 0.00 | |
| MW-634 | 2156008 | 349838 | --- | --- | 203.8 | 9.61 | 2.0 | 1.41 | 208.0 | 1.34 | 208.0 | 1.34 | 208.0 | 1.34 | 208.0 | 1.34 | |
| MW-635 | 2155946 | 351824 | 215.0 | 0.00 | 0.0 | 0.00 | 216.8 | 0.00 | 217.2 | 0.00 | 217.2 | 0.00 | 217.2 | 0.00 | 217.2 | 0.00 | |
| MW-636 | 2156157 | 352029 | 215.7 | 0.00 | 0.0 | 0.00 | 217.5 | 0.00 | 218.0 | 0.00 | 218.0 | 0.00 | 218.0 | 0.00 | 218.0 | 0.00 | |
| MW-637 | 2156357 | 352014 | 215.2 | 0.00 | 0.0 | 0.00 | 216.9 | 0.00 | 217.3 | 0.00 | 217.3 | 0.00 | 217.3 | 0.00 | 217.3 | 0.00 | |
| MW-638 | 2156432 | 351870 | --- | --- | 0.0 | 0.00 | 216.6 | 0.00 | 216.9 | 0.00 | 216.9 | 0.00 | 216.9 | 0.00 | 216.9 | 0.00 | |
| MW-639 | 2156644 | 349216 | --- | --- | --- | --- | --- | --- | 213.1 | 0.00 | 213.1 | 0.00 | 213.1 | 0.00 | 213.1 | 0.00 | |
| MW-640 | 2155084 | 349275 | --- | --- | --- | --- | --- | --- | 214.5 | 0.00 | 214.5 | 0.00 | 214.5 | 0.00 | 214.5 | 0.00 | |
| OBPZ-1 | 2155593 | 349705 | 190.1 | 0.00 | 191.4 | 0.00 | 193.3 | 0.00 | 193.7 | 0.00 | 193.7 | 0.00 | 193.7 | 0.00 | 193.7 | 0.00 | |
| OBPZ-1A | 2155591 | 349709 | 171.7 | 0.00 | 172.4 | 0.00 | 173.9 | 0.00 | 173.1 | 0.00 | 173.1 | 0.00 | 173.1 | 0.00 | 173.1 | 0.00 | |
| OBPZ-1B | 2155595 | 349700 | 190.5 | 0.00 | 191.9 | 0.00 | 193.8 | 0.00 | 194.1 | 0.00 | 194.1 | 0.00 | 194.1 | 0.00 | 194.1 | 0.00 | |
| OBPZ-2 | 2155642 | 349719 | 199.9 | 0.00 | 202.1 | 0.00 | 204.4 | 0.00 | 205.2 | 0.00 | 205.2 | 0.00 | 205.2 | 0.00 | 205.2 | 0.00 | |
| OBPZ-3 | 2155688 | 349733 | 200.7 | 0.00 | 202.8 | 0.00 | 205.2 | 0.00 | 205.9 | 0.00 | 205.9 | 0.00 | 205.9 | 0.00 | 205.9 | 0.00 | |
| PSPZ-1 | 2156220 | 351100 | 208.7 | 0.00 | 209.6 | 0.00 | 210.6 | 0.00 | 210.9 | 0.00 | 210.9 | 0.00 | 210.9 | 0.00 | 210.9 | 0.00 | |
| PSPZ-2 | 2156275 | 351364 | 210.6 | 0.45 | 211.1 | 0.41 | 212.0 | 0.39 | 212.7 | 0.38 | 212.7 | 0.38 | 212.7 | 0.38 | 212.7 | 0.38 | |
| PZ-601 | 2156180 | 351086 | 208.6 | 0.00 | 2.0 | 0.00 | 210.6 | 0.00 | 210.9 | 0.00 | 210.9 | 0.00 | 210.9 | 0.00 | 210.9 | 0.00 | |
| PZ-601A | 2156173 | 351085 | 208.7 | 0.00 | 209.7 | 0.04 | 210.8 | 0.02 | 211.1 | 0.02 | 211.1 | 0.02 | 211.1 | 0.02 | 211.1 | 0.02 | |
| PZ-602 | 2156708 | 350925 | 208.0 | 0.00 | 209.3 | 0.00 | 210.4 | 0.00 | 210.6 | 0.00 | 210.6 | 0.00 | 210.6 | 0.00 | 210.6 | 0.00 | |
| PZ-602D | 2156708 | 350935 | 180.0 | 0.00 | 180.8 | 0.00 | 181.33 | 0.00 | 181.9 | 0.00 | 181.9 | 0.00 | 181.9 | 0.00 | 181.9 | 0.00 | |
| PZ-603 | 2156518 | 351575 | 212.0 | 0.00 | 212.7 | 0.00 | 213.8 | 0.00 | 214.0 | 0.00 | 214.0 | 0.00 | 214.0 | 0.00 | 214.0 | 0.00 | |
| PZ-604 | 2156275 | 351734 | 213.0 | 0.00 | 213.6 | 0.02 | 214.8 | 0.00 | 215.0 | 0.00 | 215.0 | 0.00 | 215.0 | 0.00 | 215.0 | 0.00 | |
| PZ-605 | 2156246 | 351635 | DRY | DRY | DRY | DRY | DRY | DRY | DRY | DRY | DRY | DRY | DRY | DRY | DRY | DRY | |
| PZ-606 | 2156128 | 351640 | 212.7 | 0.48 | 213.1 | 0.34 | 214.5 | 0.00 | 214.9 | 0.00 | 214.9 | 0.00 | 214.9 | 0.00 | 214.9 | 0.00 | |
| PZ-607 | 2157472 | 349782 | 208.2 | 0.00 | 210.6 | 0.00 | 211.1 | 0.00 | 209.2 | 0.00 | 209.2 | 0.00 | 209.2 | 0.00 | 209.2 | 0.00 | |
| PZ-608 | 2156395 | 351161 | 209.3 | 1.74 | 210.3 | 1.58 | 210.1 | 0.59 | 213.0 | 0.33 | 213.0 | 0.33 | 213.0 | 0.33 | 213.0 | 0.33 | |
| PZ-609 | 2155023 | 349421 | 201.7 | 0.00 | 203.0 | 0.00 | 206.6 | 0.00 | 207.8 | 0.00 | 207.8 | 0.00 | 207.8 | 0.00 | 207.8 | 0.00 | |
| PZ-610 | 2156641 | 350037 | 206.1 | 0.00 | 207.8 | 0.00 | 209.1 | 0.00 | 209.2 | 0.00 | 209.2 | 0.00 | 209.2 | 0.00 | 209.2 | 0.00 | |
| PZ-611 | 2155919 | 348736 | 211.1 | 0.00 | 213.5 | 0.00 | 214.5 | 0.00 | 214.5 | 0.00 | 214.5 | 0.00 | 214.5 | 0.00 | 214.5 | 0.00 | |
| PZ-612 | 2156051 | 351771 | 213.7 | 0.00 | 214.3 | 0.00 | 215.5 | 0.00 | 215.9 | 0.00 | 215.9 | 0.00 | 215.9 | 0.00 | 215.9 | 0.00 | |
| PZ-891 | 2156299 | 351292 | 210.3 | 0.00 | 211.1 | 0.00 | 212.0 | 0.00 | 212.0 | 0.00 | 212.0 | 0.00 | 212.0 | 0.00 | 212.0 | 0.00 | |

Table 2. Schedule of Bioslurper Test Activities

| Pilot Test Activity | Schedule |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| Mobilization | day 1-2 |
| Site Characterization Baildown Tests and Product/Groundwater Interface Monitoring Soil-Gas Survey (limited) Monitoring Point (MP) Installation (3 MPs) Soil Sampling (TPH, BTEX, physical characteristics) | day 2-3 |
| System Installation | day 2-3 |
| Test Startup | day 3 |
| Skimmer Test (2 days) | day 3-4 |
| Bioslurper Vacuum Extraction (4 days) | day 6-9 |
| Soil-Gas Permeability Testing | day 6 |
| Skimmer Test (continued) | day 10 |
| In Situ Respiration Test — air/helium injection | day 10 |
| In Situ Respiration Test — monitoring | day 11-16 |
| Drawdown Pump Test (2 days) | day 11-12 |
| Demobilization/Mobilization | day 13-14 |

3.2 Site Characterization Tests

3.2.1 Baildown Tests

The baildown test is the primary test for selection of the bioslurper test well. Baildown tests will be performed at wells that contain measurable thicknesses of light, nonaqueous-phase liquid (LNAPL) to estimate the LNAPL recovery potential at those particular wells. In most cases, the well exhibiting the highest rate of LNAPL recovery will be selected for the bioslurper extraction well. Table 3 presents the volume of fuel that would be present in a 1-foot measured thickness for various size wells. Detailed procedures for the baildown tests are provided in Section 5.6 of the generic Bioslurping Protocol.

Table 3. Volumes Per Unit Length for Common Well Casing Diameters

| Nominal Pipe Size | Gal/ft (Schedule 40 Pipe) | Gal/ft (Schedule 80 Pipe) |
|------------------------------|--------------------------------------|--------------------------------------|
| 2.0 | 0.174 | 0.153 |
| 3.0 | 0.384 | 0.343 |
| 4.0 | 0.661 | 0.597 |
| 6.0 | 1.50 | 1.35 |

3.2.2 Soil-Gas Survey (Limited)

A small-scale soil-gas survey will be conducted to identify the best location for installation of the bio-slurping system. The soil-gas survey will be conducted in areas where historical site data indicate the highest contamination levels. In Table 1, the heavily contaminated wells appear in bold type. The area around these wells will be surveyed to select the locations for installation of soil-gas monitoring points. Soil-gas surveying will be concentrated around areas that exhibit the following characteristics.

1. Soil vapor from the site will exhibit high total petroleum hydrocarbon (TPH) concentrations (10,000 ppm or greater).
2. Soil vapor will contain relatively low oxygen concentrations (between 0% and 2%).
3. Soil vapor will have relatively high carbon dioxide concentrations (depending on soil type, between 2% and 10% or greater).

To obtain further information about the soil-gas survey, consult Section 5.2 of the generic Bioslurping Protocol.

3.2.3 Monitoring Point Installation

- Monitoring points must be installed to determine the radius of influence that the free-product recovery system has on vadose zone contaminated soils. A general arrangement of the bioslurping well and monitoring points is shown in Figure 2.

Upon conclusion of the initial soil-gas survey and baildown tests, at least three soil-gas monitoring points will be installed to measure soil-gas changes that occur during the operation of the bioslurper. These monitoring points should be located in highly contaminated soils within the free-phase plume and should be positioned to allow detailed monitoring of the in situ changes in soil-gas composition caused by the bioslurper system. The components of soil-gas monitoring points are shown in Figure 3. A conceptual arrangement for soil-gas monitoring points in Well #COE-2T at the UST area in the POL Depot is presented in Figure 4. Information on monitoring point installation can be found in Section 4.2.1 of the generic Bioslurping Protocol.

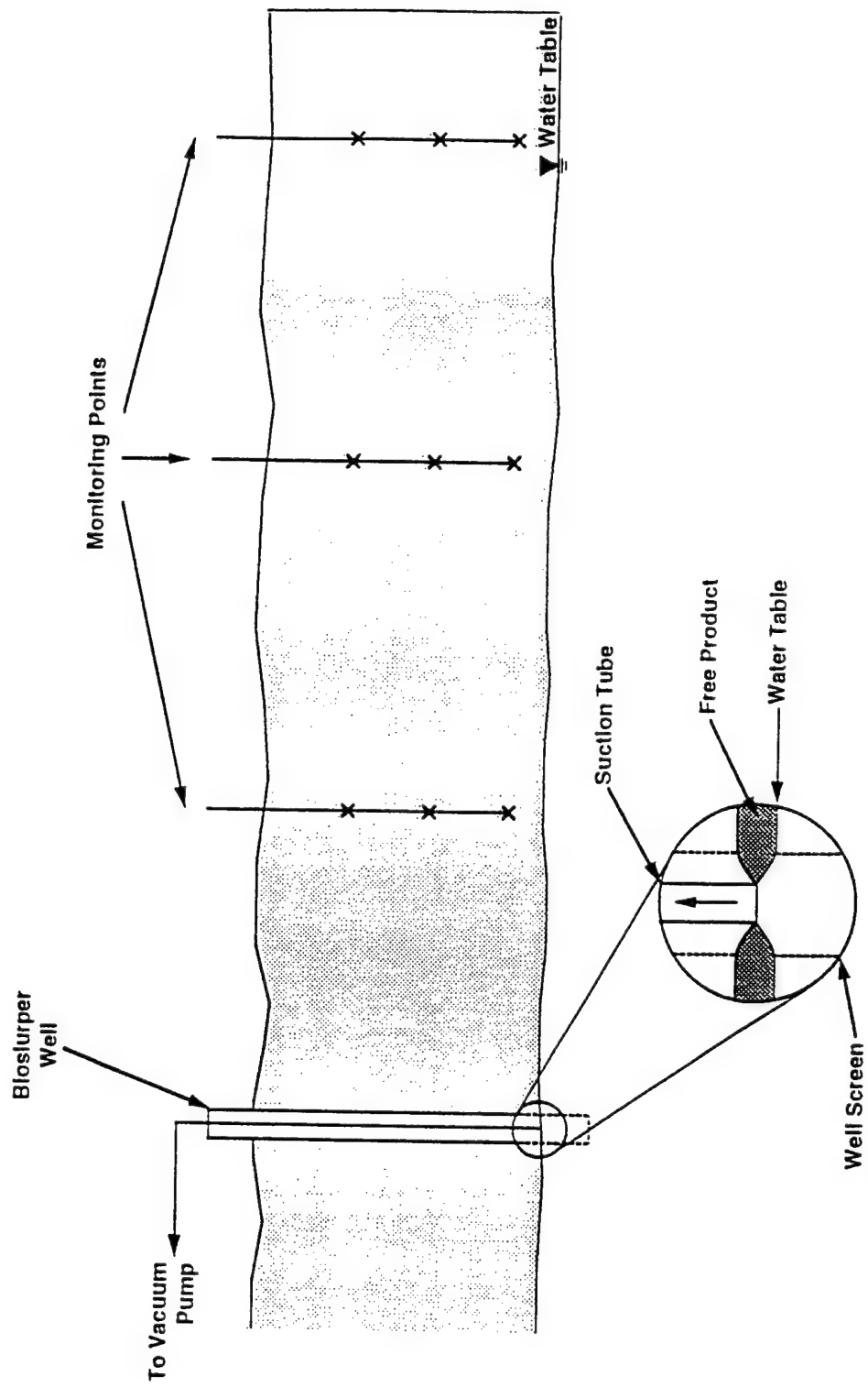


Figure 2. General Bioslurper Well and Monitoring Point Arrangement

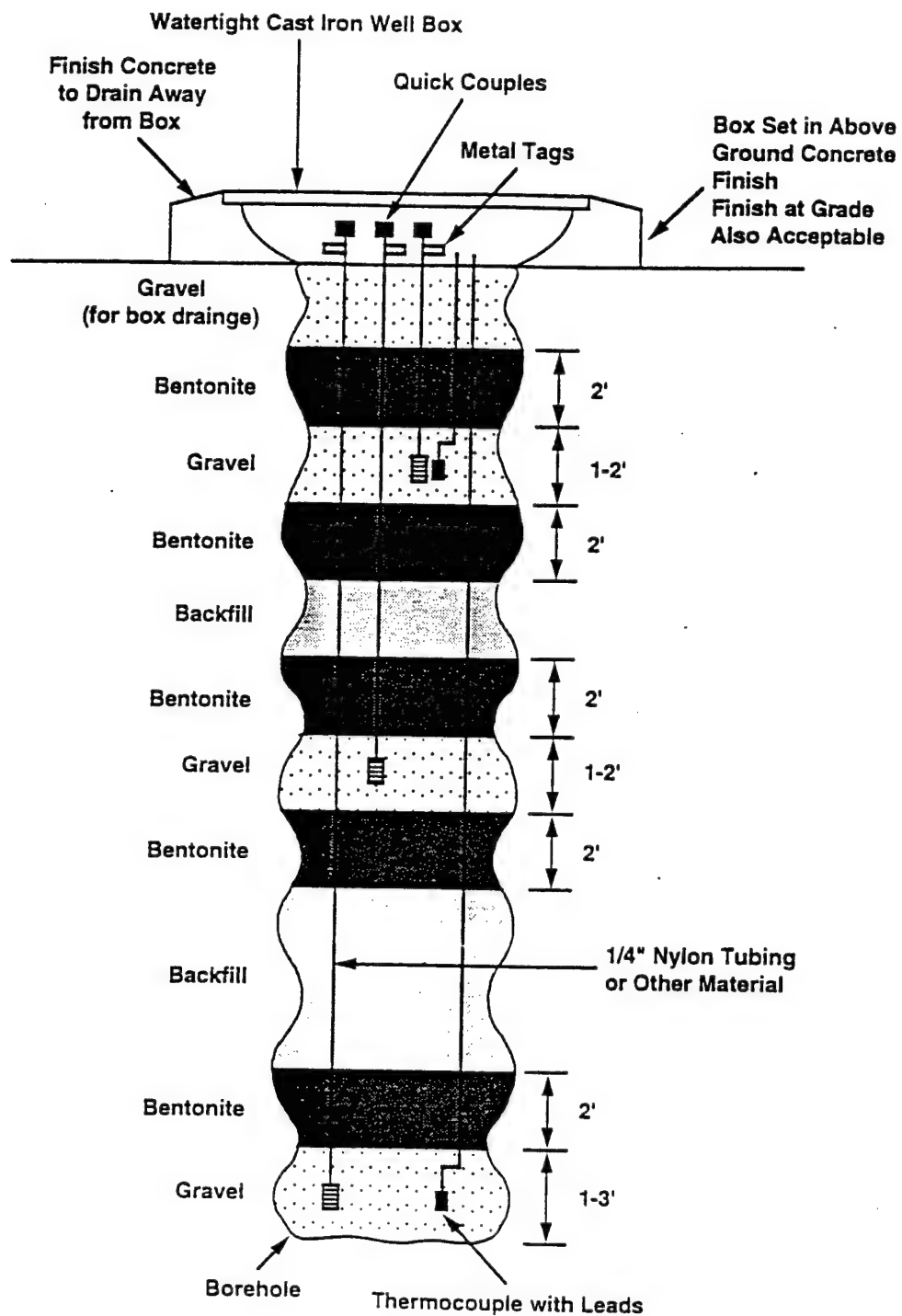


Figure 3. Diagram of a Typical Bioslurper Soil-Gas Monitoring Point

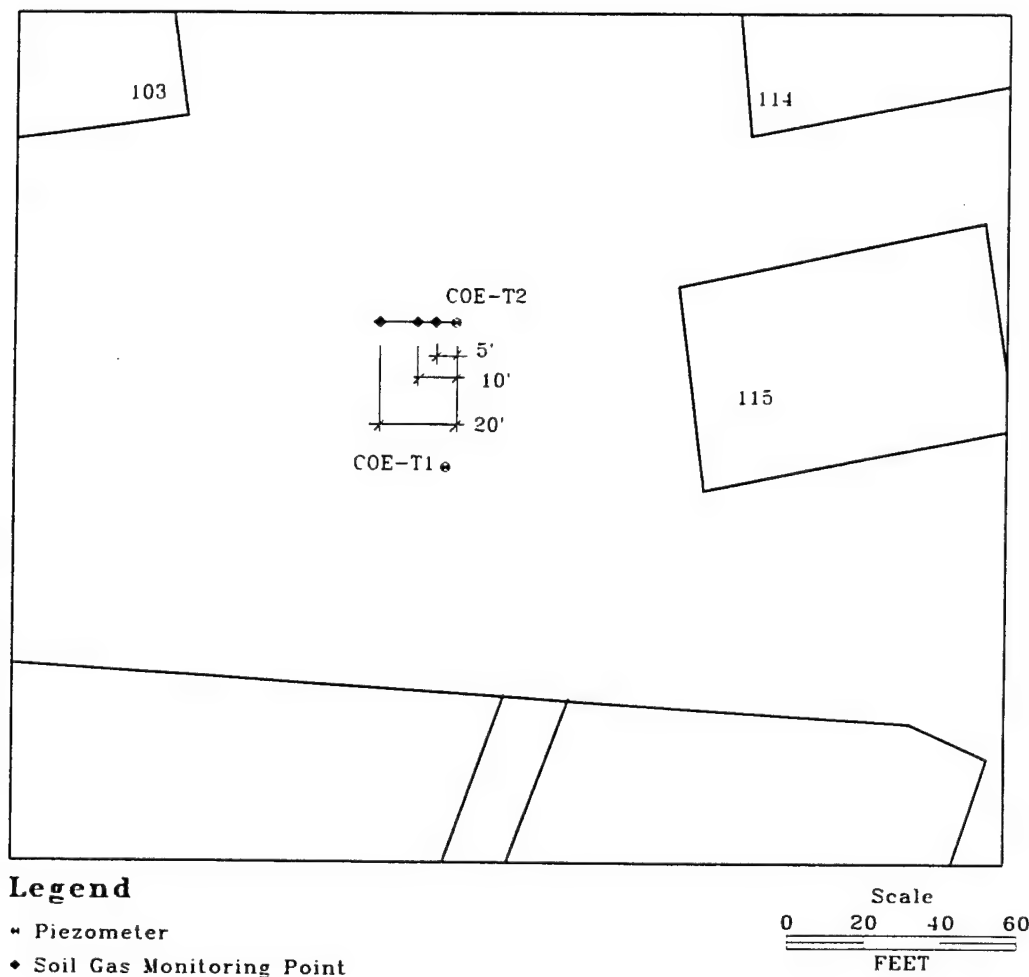


Figure 4. Conceptual Arrangement for Soil-Gas Monitoring Points at UST Area.

3.2.4 Soil Sampling

Soil samples will be collected to determine the physical and chemical composition of the soil near the bioslurper test site. Soil samples will be collected from the boreholes advanced for monitoring point installation at two or three locations at the site chosen for the bioslurper test. Generally, samples will be collected from the capillary fringe over the free product.

Soil samples will be analyzed for particle-size distribution, bulk density, porosity, moisture content, BTEX, and TPH. Section 5.5.1 of the generic Bioslurping Protocol will be consulted for information on the field measurements and sample collection procedures for soil sampling.

3.3 Bioslurper System Installation and Operation

Once the well to be used for the bioslurper test installation at Shaw AFB has been identified, the bioslurper pump and support equipment will be installed and the pilot test will be initiated.

3.3.1 System Setup

After the preliminary site characterization has been completed and the bioslurper candidate well has been selected, the previously shipped equipment will be mobilized from the holding facility to the test site, and the bioslurper system will be assembled. Figure 5 shows a flow diagram of the bioslurper process. Figure 6 is a generic diagram of the bioslurper extraction well that will be installed at Shaw AFB.

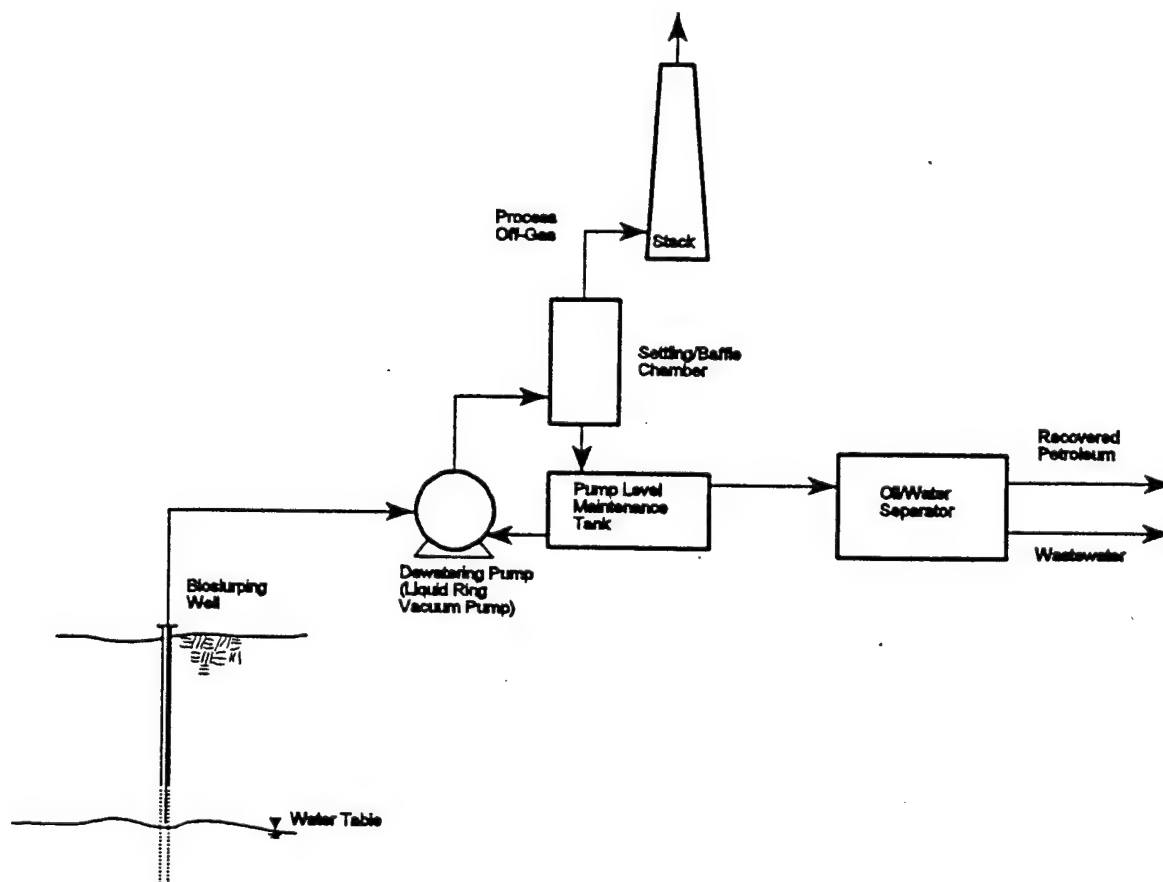


Figure 5. Bioslurper Process Flow

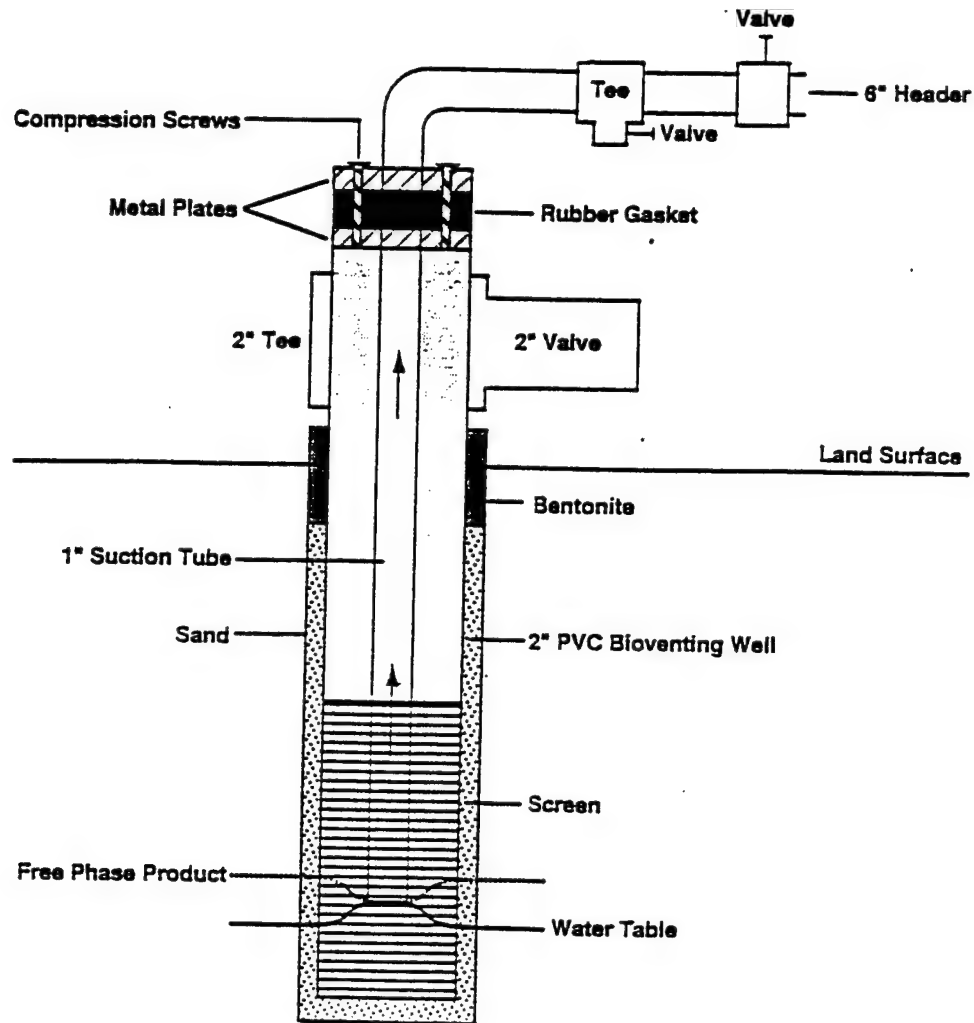


Figure 6. Diagram of a Typical Bioslurper Well

Before the LNAPL recovery tests are initiated, all relevant baseline field data will be collected and recorded. These data will include soil-gas concentrations, initial soil-gas pressures, the depth to groundwater, and the LNAPL thickness. Ambient soil and all atmospheric conditions (e.g., temperature, humidity, barometric pressure) also will be recorded. All emergency equipment (i.e., emergency shutoff switches and fire extinguishers) will be installed and checked for proper operation at this time.

A clear, level area near the well selected for the bioslurper test installation will be identified for the 20' x 10' flatbed trailer that holds the equipment required for bioslurper system operation. For more information on bioslurper system installation, consult Section 6.0 of the generic Bioslurping Protocol.

3.3.2 System Shakedown

A brief startup test will be conducted to ensure that the system is constructed properly and operates safely. All system components will be checked for problems and/or malfunctions. A checklist will be provided to document the system shakedown.

3.3.3 System Startup and Test Operations

After installation is complete and the bioslurper system is confirmed to be operating properly, the LNAPL recovery tests will be started. The Bioslurper Initiative has been designed to evaluate the effectiveness of bioslurping as an LNAPL recovery technology relative to conventional gravity-driven LNAPL recovery technologies. The Bioslurper Initiative includes three separate LNAPL recovery tests: (1) a skimmer simulation test, (2) a vacuum-assisted bioslurper test, and (3) a groundwater drawdown LNAPL recovery test. The three recovery tests are described in detail in Section 7.3 of the generic Bioslurping Protocol.

The bioslurper system operating parameters that will be measured during operation are vapor discharge, aqueous effluent, LNAPL recovery volume rates, vapor discharge volume rates, and groundwater discharge volume rates. Vapor monitoring will consist of continuous on-line monitoring of TPH supplemented by two samples collected for detailed laboratory analysis. A total of two samples of aqueous effluent will be collected for analysis of BTEX and TPH content. Recovered LNAPL volume will be recorded using an in-line flow-totalizing meter. The off-gas discharge volume will be measured using a calibrated pitot tube, and groundwater discharge volume will be recorded using an in-line flow-totalizing meter. Section 8.0 of the generic Bioslurping Protocol describes process monitoring of the bioslurper system.

3.3.4 Soil-Gas Permeability Test

A soil-gas permeability test will be conducted concurrently with startup of the vacuum-assisted bioslurper operation. Soil-gas permeability data will support the process of estimating the vadose zone radius of influence of the bioslurper system. Soil-gas permeability results also will aid in determining the number of wells required if it is decided to treat the site with a large-scale bioslurper system. The soil-gas permeability test method is described in Section 5.7 of the generic Bioslurping Protocol.

3.3.5 In Situ Respiration Test

The oxygen utilization rate will be used to estimate the biodegradation rate at the site. An in situ respiration test will be conducted after completion of the bioslurper operating tests. The in situ respiration testing will involve injection of air/helium injection into selected soil-gas monitoring points followed by monitoring changes in concentration of oxygen, carbon dioxide, petroleum hydrocarbons, and helium in soil-gas near the injection point. Measurement of the soil-gas composition typically will be conducted at 2, 4, 6, and 8 hours and then every 4 to 12 hours for about 2 days. Timing of the tests will be adjusted based on oxygen-use rate. If oxygen depletion occurs rapidly, more frequent monitoring will be required. If oxygen depletion is slow, less frequent readings will be acceptable. Further information on the procedures and data collection for in situ respiration testing is given in Section 5.8 of the generic Bioslurping Protocol.

3.3.6 Extended Testing

The Air Force has the option of extending the operation of the bioslurper system for up to 6 months if LNAPL recovery rates are promising. If extended testing is to be performed, the Air Force will need to provide electrical power for long-term operation of the bioslurper pump. Disposition of all generated wastes and routine operation and maintenance of the system will be the Air Force's responsibility. Battelle will provide technical support during the extended testing operation.

3.4 Demobilization

Once all necessary tests have been completed at the Shaw AFB site, the equipment will be disassembled by Battelle staff. The equipment then will be moved back to a holding facility, where it will remain until its next destination is determined. Battelle staff will receive this information and will be responsible for shipment of the equipment to the next site before departing from Shaw AFB.

4.0 BIOSLURPER SYSTEM DISCHARGE

4.1 Vapor Discharge Disposition

Battelle expects that the operation of the bioslurper test system at the Shaw AFB site will require a waiver or a point source air release registration and may require some additional permits. However, due to the short duration of the bioslurper pilot test, it can be assumed that concentration of TPH released to the atmosphere will be approximately 65 lb TPH/day. This value is based on the average TPH discharge level at two bioslurper test sites (Wright-Patterson AFB and Travis AFB) that are contaminated with the same type of jet fuel as that found at the Shaw POL site. The value may vary depending on the TPH concentration of the soil gas and the permeability of the soil. The discharge of benzene is estimated to be less than 1 lb/day.

The data for the TPH and benzene discharge levels at four previous bioslurper sites are presented in Table 4. The large TPH discharge level at Travis AFB is partially due to the extraction rate of the vapors. This extraction rate is the maximum rate a 3-hp pump will achieve and should be lower at Shaw AFB due to the permeability of the soils. The vapor stream generated by the bioslurper system may be discharged directly to the atmosphere because of the short duration of the test and the low concentration levels of TPH and benzene in the stream.

Table 4. Benzene and TPH Discharge Levels at Previous Bioslurper Test Sites

| Site Location | Fuel Type | Extraction Rate (scfm) | Benzene (ppmv) | TPH (ppmv) | Benzene Discharge (lb/day) | TPH Discharge (lb/day) |
|-----------------------|----------------|------------------------|----------------|------------|----------------------------|------------------------|
| Wright-Patterson AFB | Jet Fuel | 3 | nd | 595 | 0.0 | 1.0 |
| Bolling AFB (Site #1) | No. 2 Fuel Oil | 4 | 0.2 | 153 | 0.0003 | 0.009 |
| Bolling AFB (Site #2) | Gasoline | 21 | 370 | 70,000 | 2.3 | 470.1 |
| Andrews AFB | No. 2 Fuel Oil | 8 | 16 | 2,000 | 0.001 | 0.2 |
| Travis AFB | Jet Fuel | 20 | 100 | 10,800 | 0.58 | 126.4 |

nd = not detected

To ensure the safety and regulatory compliance of the bioslurper system, vapor discharge samples (TPH, O₂, and CO₂) will be collected periodically throughout the bioslurper pilot test, and field soil-gas screening instruments will be used to monitor vapor discharge concentration variability. The volume of vapor discharge will be monitored daily using air flow instruments. If state regulatory requirements will not permit the expected amount of organic vapor discharge to the atmosphere, the Base POC should inform AFCEE and Battelle so that alternative plans can be made prior to mobilization to the site. Table 5 presents information typically required to complete an air release registration form.

Table 5. Air Release Summary Information

| Data Item | Air Release Information |
|---------------------------------------------------------------|-----------------------------------------------|
| Contractor Point of Contact | Jeff Kittel, (614) 424-6122 |
| Contractor address | Battelle, 505 King Avenue, Columbus, OH 43201 |
| Estimated total quantity of petroleum product to be recovered | TBD |
| Description of petroleum product to be recovered | JP-4 jet fuel |
| Planned date of test start | TBD |
| Test duration | 9 days (active pumping) |
| Maximum expected VOC concentration in air | ~65 lb/day (64 lb TPH, < 1.0 lb benzene) |
| Maximum total quantity of VOC release | ~65 lb/day |
| Expected contaminants in air release | TPH, benzene (<0.2 mg/L) |
| Expected quantity of fuel use (for electrical generator) | 125 gal |
| Type of fuel used | Gasoline and diesel fuel |
| Stack height above ground level | 10 ft |

4.2 Aqueous Influent/Effluent Disposition

The flowrate of groundwater pumped by the bioslurper will be less than 5 gpm. However, in South Carolina it may be necessary to obtain a groundwater pumping waiver or registration permit. If one is required, the Base POC will inform Battelle of the necessary steps in obtaining the waiver or permit.

Operation of the bioslurper system will generate an aqueous waste discharge that will be passed through an oil/water separator. The intention of Battelle staff will be to dispose of the wastewater by discharge directly to the Base wastewater treatment facility. If existing Base wastewater channels can be used, no National Pollutant Discharge Elimination System (NPDES) or other water discharge permits will be required.

4.3 Free-Product Recovery Disposition

The bioslurper system will recover free-phase product from the pilot tests performed at Shaw AFB. Free product recovered by the bioslurping tests will be turned over to the Base for disposal and/or recycling. The volume of free product recovered from the Base will not be known until the tests have been performed. The maximum recovery rate for this system is 5 gpm, but the actual rate of LNAPL recovery likely will be much lower.

5.0 SCHEDULE

The schedule for the bioslurper fieldwork at Shaw AFB will depend on approval of the project test plans. Battelle will determine a definitive schedule as soon as possible after approval is received. Battelle will have two to three staff members on site for approximately 2 weeks to conduct all necessary pilot testing. At the conclusion of the field testing at Shaw AFB, all staff will return their Base passes. Battelle staff will remove all bioslurper field testing equipment from the Base before they leave the site.

6.0 PROJECT SUPPORT ROLES

This section outlines some of the major functions of personnel from Battelle, Shaw AFB, and AFCEE during the bioslurper field test.

6.1 Battelle Activities

Battelle is responsible in the Bioslurper Initiative at Shaw AFB will be to supply all the necessary staff and equipment to perform all the tests on the bioslurper system. Battelle also will provide technical support in the areas of water and vapor discharge permitting, digging permits, staff support during the extended testing period, and any other technical areas that need to be addressed.

6.2 Shaw AFB Support Activities

To support the necessary field tests at Shaw AFB, the Base must be able to provide the following:

1. Any digging permits and utility clearances that need to be obtained prior to the initiation of the fieldwork. Any underground utilities should be clearly marked to reduce the chance of utility damage and/or personal injury during soil-gas probe and possible well installation. Battelle will not begin field operations without these clearances and permits.
2. The Air Force will be responsible for obtaining Base and site clearance for the Battelle staff that will be working at the Base. The Base POC will be furnished with all necessary information on each staff member at least 1 week prior to field startup.
3. Access to the local sanitary sewer must be furnished so that Battelle staff can discharge the bioslurper aqueous effluent directly to the Base treatment facility.
4. Regulatory approval, if required, must be obtained by the Base POC prior to startup of the bioslurper pilot test. As stated previously, it is likely that a waiver to allow air releases or a point source air release registration will be required for emissions of approximately 65 lb/day of TPH. The TPH and benzene concentration levels are the maximum levels of those components that would be released to the atmosphere. The Base POC will obtain all necessary Base permits prior to mobilization to the site. Battelle will provide technical assistance in preparing regulatory approval documents.

5. The Base also will be responsible for the disposition of all waste generated from the pilot testing. Such waste includes any soil cuttings generated from drilling, and all aqueous wastestreams produced from the bioslurper tests. All free product recovered from the bioslurper operation will be disposed of or recycled by the Base. Battelle will provide technical assistance in disposing of the waste generated from the bioslurper pilot test.
6. Before field activities begin, the Health and Safety Plan will be finalized with information provided by the Base POC. Table 6 is a checklist for the information required to complete the Health and Safety Plan. All emergency information will be obtained by the Site Health and Safety Office before operations begin.

Table 6. Health and Safety Information Checklist

| <u>Emergency Contacts</u> | <u>Name</u> | <u>Telephone Number</u> |
|-------------------------------------------|-------------|-----------------------------|
| Hospital Emergency Room: | _____ | _____ |
| Point of Contact: | _____ | _____ |
| Fire Department: | _____ | _____ |
| Emergency Unit (Ambulance): | _____ | _____ |
| Security: | _____ | _____ |
| Explosives Unit: | _____ | _____ |
| Community Emergency Response Coordinator: | _____ | _____ |
| Other: | _____ | _____ |
| <u>Program Contacts</u> | | |
| Air Force: | _____ | _____ |
| Battelle: | _____ | _____ |
| Other: | _____ | _____ |
| <u>Emergency Routes</u> | | |
| Hospital (maps attached) | _____ | _____ |
| Other: | _____ | |

6.3 AFCEE Activities

The Air Force Center for Environmental Excellence (AFCEE) POC will act as a liaison between Battelle and Shaw Base staff. The AFCEE POC will ensure that all necessary permits are obtained and the space required to house the bioslurper field equipment is found.

The following is a listing of Battelle, AFCEE, and Shaw Base staff who can be contacted in cases of emergency and/or required technical support during the bioslurper field initiative tests at Shaw AFB.

| | | |
|----------------|---------------|--------------|
| Battelle POCs | Jeff Kittel | 614-424-6122 |
| | Eric Drescher | 614-424-3088 |
| AFCEE POC | Patrick Haas | 210-536-4314 |
| Shaw AFB POC | _____ | _____ |
| Regulator POCs | | |
| Air: | _____ | _____ |
| Water: | _____ | _____ |

APPENDIX A
WELL CONSTRUCTION SUMMARY SHEET

Table 2-2. Well Construction Summary
Operable Unit #1, POL Depot
Shaw Air Force Base, South Carolina

22-Jul-93

| Well Designation | Previous Designation | Coordinates ^{1A} | | Elevations (ft, msl) | | | Depth ^{1C} | |
|------------------|----------------------|---------------------------|------------|----------------------|---------------------------------|-------------|---------------------|-------------------|
| | | Easting | Northing | Ground Surface | Protective Casing ^{1B} | Well Casing | Total ^{1D} | Screened Interval |
| MW-634 | ^{1B} MW-7 | 2156008.302 | 349838.416 | 246.58 | 246.66 | 246.46 | 52.9 | 37.6 - 52.6 |
| MW-635 | ^{1B} V | 2155945.729 | 351823.946 | 259.83 | 259.80 | 259.28 | 55.1 | 40 - 55 |
| MW-636 | ^{1B} W | 2156156.802 | 352028.675 | 259.38 | 259.49 | 258.84 | 54.35 | 40 - 55 |
| MW-637 | ^{1B} X | 2156357.121 | 352014.293 | 255.70 | 256.03 | 255.44 | 54 | 39 - 54 |
| MW-638 | ^{1B} Y | 2156431.696 | 351870.151 | 252.61 | 252.92 | 252.05 | 53.45 | 39 - 54 |
| MW-639 | ^{1B} - | 2155644.432 | 349215.727 | 250.19 | 250.19 | 249.93 | 48.7 | 33.4 - 48.4 |
| MW-640 | ^{1B} - | 2155084.241 | 349275.395 | 251.51 | 251.43 | 251.11 | 46.6 | 31.3 - 46.3 |
| MW-641 | ^{1B} B-642 | 2155406.393 | 349776.899 | 254.41 | 254.56 | 254.56 | 74.4 | 59.1 - 74.1 |
| RW-4 | ^{1A} | 2156207.601 | 351533.016 | 253.97 | | 252.30 | 60 | 34.5 - 59.5 |
| RW-5 | ^{1A} | 2156205.348 | 351466.093 | 253.16 | | 251.78 | 61.5 | 36 - 61 |
| RW-6 | ^{1A} | 2156328.195 | 351484.191 | 252.58 | | 250.93 | 61 | 30.5 - 60.5 |
| RW-7 | ^{1A} | 2156287.389 | 351424.690 | 252.74 | | 251.29 | 61 | 30.2 - 60.2 |
| RW-8 | ^{1A} | 2156374.873 | 351424.936 | 251.52 | | 249.93 | 63 | 32 - 62 |
| RW-9 | ^{1A} | 2156323.021 | 351361.703 | 252.57 | | 251.34 | 63 | 32 - 62 |
| RW-10 | ^{1A} | 2156354.400 | 351252.630 | 251.77 | | 249.98 | 66 | 35 - 65 |
| RW-11 | ^{1A} | 2156433.958 | 351251.746 | 250.43 | | 249.17 | 66 | 30 - 65 |
| RW-12 | ^{1A} | 2156386.661 | 351161.866 | 250.92 | | 249.22 | 72 | 31.7 - 61.7 |

^{1A} = S.C. State Plane Grid Coordinates Surveyed by CARDAN Systems Corp. or Palmer and Mallard.

^{1B} = Steel Protective Casing if Present, or Steel Manhole Lip if Flush Surface Completion

^{1C} = Feet Below Land Surface

^{1D} = Base of Well Casing/Screen.

¹¹ = Wells Installed by LAW Environmental (1986-1990).

¹² = Wells Installed by USACE

¹³ = Wells Installed by Geraghty & Miller, Inc. (1991-1993).

¹⁴ = Wells Installed by Research Triangle Institute (1984).

APPENDIX B
LABORATORY ANALYTICAL REPORTS

@ AIR TOXICS LTD.

AN ENVIRONMENTAL ANALYTICAL LABORATORY

WORK ORDER #: 9607191

Work Order Summary

CLIENT: Ms. Amanda Bush
Battelle Memorial Institute
505 King Avenue
Columbus, OH 43201-2693

BILL TO: Same

PHONE: 614-424-4996
FAX: 614-424-3667
DATE RECEIVED: 7/18/96
DATE COMPLETED: 7/26/96

INVOICE # 11061
P.O. # 91221
PROJECT # Shaw AFB
AMOUNT\$: \$421.61

| <u>FRACTION #</u> | <u>NAME</u> | <u>TEST</u> | <u>RECEIPT</u> <u>VAC./PRES.</u> | <u>PRICE</u> |
|-------------------|-------------|-------------|-------------------------------------|--------------|
| 01A | SHW-AE-1 | TO-3 | 2.5 "Hg | \$120.00 |
| 02A | SHW-AE-2 | TO-3 | 1.0 "Hg | \$120.00 |
| 03A | SHW-AE-3 | TO-3 | 0 "Hg | \$120.00 |
| 04A | Lab Blank | TO-3 | NA | NC |

| | | |
|---------------|--------------------------------------------------------|---------|
| Misc. Charges | 1 Liter Summa Canister Preparation (3) @ \$15.00 each. | \$45.00 |
| | Shipping (7/3/96) | \$16.61 |

CERTIFIED BY: Battelle C. Crume
for Laboratory Director

DATE: 7/26/96

AIR TOXICS LTD.

SAMPLE NAME: SHW-AE-1

ID#: 9607191-01A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

| | | | | | |
|---------------|----------------------|----------------------|------------------|-----------------------------|--|
| File Name: | | 6071909 | | Date of Collection: 7/13/96 | |
| Dil. Factor: | | 22000 | | Date of Analysis: 7/19/96 | |
| Compound | Det. Limit (ppmv) | Det. Limit (uG/L) | Amount (ppmv) | Amount (uG/L) | |
| Benzene | 22 | 71 | 1900 | 6200 | |
| Toluene | 22 | 84 | 1900 | 7300 | |
| Ethyl Benzene | 22 | 97 | 1200 | 5300 | |
| Total Xylenes | 22 | 97 | 2400 | 10000 | |

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as JP-4 Jet Fuel)

| | | | | |
|-------------------------|----------------------|-----------------------------|------------------|------------------|
| File Name: | 6071909 | Date of Collection: 7/13/96 | | |
| Dil. Factor: | 22000 | Date of Analysis: 7/19/96 | | |
| Compound | Det. Limit (ppmv) | Det. Limit (uG/L) | Amount (ppmv) | Amount (uG/L) |
| TPH* (C5+ Hydrocarbons) | 220 | 1400 | 13000 | 84000 |
| C2 - C4** Hydrocarbons | 220 | 400 | 480 | 880 |

*TPH referenced to JP-4 Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: SHW-AE-2

ID#: 9607191-02A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

| | | | | |
|---------------|----------------------|-----------------------------|------------------|------------------|
| File Name: | 6071911 | Date of Collection: 7/14/96 | | |
| Dil. Factor: | 11000 | Date of Analysis: 7/19/96 | | |
| Compound | Det. Limit (ppmv) | Det. Limit (uG/L) | Amount (ppmv) | Amount (uG/L) |
| Benzene | 11 | 36 | 700 | 2300 |
| Toluene | 11 | 42 | 1100 | 4200 |
| Ethyl Benzene | 11 | 49 | 590 | 2600 |
| Total Xylenes | 11 | 49 | 1200 | 5300 |

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as JP-4 Jet Fuel)

| | | | | |
|-------------------------|----------------------|-----------------------------|------------------|------------------|
| File Name: | 6071911 | Date of Collection: 7/14/96 | | |
| Dil. Factor: | 11000 | Date of Analysis: 7/19/96 | | |
| Compound | Det. Limit (ppmv) | Det. Limit (uG/L) | Amount (ppmv) | Amount (uG/L) |
| TPH* (C5+ Hydrocarbons) | 110 | 710 | 12000 | 78000 |
| C2 - C4** Hydrocarbons | 110 | 200 | 960 | 1800 |

*TPH referenced to JP-4 Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: SHW-AE-3

ID#: 9607191-03A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

| | | | | |
|---------------------|-------------------|-----------------------------|---------------|---------------|
| File Name: 6071913 | | Date of Collection: 7/16/96 | | |
| Dil. Factor: 202000 | | Date of Analysis: 7/19/96 | | |
| Compound | Det. Limit (ppmv) | Det. Limit (uG/L) | Amount (ppmv) | Amount (uG/L) |
| Benzene | 200 | 650 | 11000 | 36000 |
| Toluene | 200 | 770 | 14000 | 54000 |
| Ethyl Benzene | 200 | 880 | 9800 | 43000 |
| Total Xylenes | 200 | 880 | 20000 | 88000 |

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as JP-4 Jet Fuel)

| | | | | |
|-------------------------|------------|-----------------------------|--------|--------|
| File Name: | 6071913 | Date of Collection: 7/16/96 | | |
| Dil. Factor: | 202000 | Date of Analysis: 7/19/96 | | |
| | Det. Limit | Det. Limit | Amount | Amount |
| Compound | (ppmv) | (uG/L) | (ppmv) | (uG/L) |
| TPH* (C5+ Hydrocarbons) | 2000 | 13000 | 130000 | 840000 |
| C2 - C4** Hydrocarbons | 2000 | 3700 | 9300 | 17000 |

*TPH referenced to JP-4 Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: Lab Blank

ID#: 9607191-04A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

| File Name: 6071906 | | Date of Collection: NA | | |
|--------------------|----------------------|---------------------------|------------------|------------------|
| Dil. Factor: 1.00 | | Date of Analysis: 7/19/96 | | |
| Compound | Det. Limit (ppmv) | Det. Limit (uG/L) | Amount (ppmv) | Amount (uG/L) |
| Benzene | 0.001 | 0.003 | Not Detected | Not Detected |
| Toluene | 0.001 | 0.004 | Not Detected | Not Detected |
| Ethyl Benzene | 0.001 | 0.004 | Not Detected | Not Detected |
| Total Xylenes | 0.001 | 0.004 | Not Detected | Not Detected |

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as JP-4 Jet Fuel)

| File Name: 6071906 | | Date of Collection: NA | | |
|-------------------------|----------------------|---------------------------|------------------|------------------|
| Dil. Factor: 1.00 | | Date of Analysis: 7/19/96 | | |
| Compound | Det. Limit (ppmv) | Det. Limit (uG/L) | Amount (ppmv) | Amount (uG/L) |
| TPH* (C5+ Hydrocarbons) | 0.010 | 0.065 | Not Detected | Not Detected |
| C2 - C4** Hydrocarbons | 0.010 | 0.018 | Not Detected | Not Detected |

*TPH referenced to JP-4 Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: NA



180 BLUE RAVINE ROAD, SUITE B
FOLSOM, CA 95630-4719
(916) 985-1000 FAX: (916) 985-1020

CHAIN-OF-CUSTODY RECORD

Nº 007724

Page 1 of 1[illegible]

**Alpha Analytical, Inc.**

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Las Vegas, Nevada 89120
(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: Shaw AFB Pilot Test
Phone: (614) 424-6199
Attn:

Sampled: 07/13-15/96 Received: 07/18/96 Analyzed: 07/24/96

Matrix: [] Soil [X] Water [] Waste

Analysis Requested: TPH - Total Petroleum Hydrocarbons-Purgeable
Quantitated As Gasoline

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191

Results:

| Client ID/ Lab ID | Parameter | Concentration mg/L | Detection Limit mg/L |
|--------------------------|-----------------|-----------------------|----------------------------|
| SHWDC 2 /BMI071896-05 | TPH (Purgeable) | 3.0 | 0.50 |
| SHWDC 4 /BMI071896-07 | TPH (Purgeable) | 2.9 | 0.50 |
| SHWDC 6 /BMI071896-09 | TPH (Purgeable) | 2.3 | 0.50 |

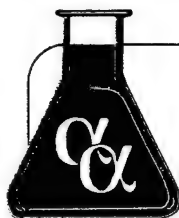
ND - Not Detected

Approved by:

Roger L. Scholl
Roger L. Scholl, Ph.D.
Laboratory Director

Date:

8/1/96

**Alpha Analytical, Inc.**

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1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: Shaw AFB Pilot Test
Phone: (614) 424-6199
Attn:

Sampled: 07/13-15/96 Received: 07/18/96 Analyzed: 07/23/96

Matrix: [] Soil [X] Water [] Waste

Analysis Requested: BTEX - Benzene, Toluene, Ethylbenzene, Xylenes

Methodology: BTEX - EPA Method 624/8240

Results:

| Client ID/ Lab ID | Parameter | Concentration ug/L | Detection Limit ug/L |
|--------------------------|---------------|-----------------------|----------------------------|
| SHWDC 1 /BMI071896-04 | Benzene | 62 | 50 |
| | Toluene | 310 | 50 |
| | Ethylbenzene | 110 | 50 |
| | Total Xylenes | 640 | 50 |
| SHWDC 3 /BMI071896-06 | Benzene | 76 | 50 |
| | Toluene | 300 | 50 |
| | Ethylbenzene | 97 | 50 |
| | Total Xylenes | 610 | 50 |
| SHWDC 5 /BMI071896-08 | Benzene | 110 | 50 |
| | Toluene | 320 | 50 |
| | Ethylbenzene | 100 | 50 |
| | Total Xylenes | 630 | 50 |

ND - Not Detected

Convert Conc

Approved by:

Roger L. Scholl
Roger L. Scholl, Ph.D.
Laboratory Director

1/1/96

Laboratory
Analysis Report



Sierra
Environmental
Monitoring, Inc.

ALPHA ANALYTICAL
255 GLENDALE AVENUE, SUITE 21
SPARKS NV 89431

Date : 8/02/96
Client : ALP-855
Taken by: CLIFNT
Report : 16922
PO# :

Page: 1

| Sample | Collected | | MOISTURE CONTENT % | DENSITY G/CM3 | POROSITY % | PARTICLE SIZE DISTRIBUTION FRACTION % | | |
|------------------------|-----------|-------|--------------------------|------------------|---------------|---------------------------------------------|--|--|
| | Date | Time | | | | | | |
| BM1071896-02 - SHW-S-1 | 7/10/96 | 12:03 | 1.8 | 1.52 | 42.7 | See Report | | |
| BM1071896-03 - SHW-S-2 | 7/10/96 | 13:10 | 2.3 | 1.42 | 46.4 | See Report | | |

Approved By: 

This report is applicable only to the sample received by the laboratory. The liability of the laboratory is limited to the amount paid for this report. This report is for the exclusive use of the client to whom it is addressed and upon the condition that the client assumes all liability for the further distribution of the report or its contents.

William F. Pillsbury
President

1135 Financial Blvd.
Reno, NV 89502
Phone (702) 857-2400
FAX (702) 857-2404

John C. Seher
Manager



Sierra
Environmental
Monitoring, Inc.

August 2, 1996

TO: Alpha Analytical
FROM: Sierra Environmental Monitoring, Inc.
RE: Particle Size Distribution Analysis for Samples:
SEM 9607-0804 BMI 071896-02-SHW-S1
SEM 9607-0805 BMI 071896-03-SHW-S1


As per your request, we have performed particle size analysis on the samples submitted to our laboratory. Test results are as follows:

| | | | |
|-----------|-------------|-------------|--------------|
| 9607-0804 | Clay: 0.0 % | Silt: 1.9 % | Sand: 98.1 % |
| 9607-0805 | Clay: 0.0 % | Silt: 1.9 % | Sand: 98.1 % |

The samples were passed through a #10 sieve prior to analysis as per procedure. All results are based on oven dry sample weights.

We appreciate this opportunity to provide our laboratory testing services. If you have any questions or require further testing, please feel free to contact us at your convenience.

Sincerely,
SIERRA ENVIRONMENTAL MONITORING, INC.


John Seher
Laboratory Manager

**Alpha Analytical, Inc.**

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1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: 91222
Phone: (614) 424-6199
Attn: Martin Wheeler

Sampled: 07/10/96 Received: 07/18/96 Analyzed: 07/23/96

Matrix: [X] Soil [] Water [] Waste

Analysis Requested: TPH - Total Petroleum Hydrocarbons-Purgeable
Quantitated As Gasoline

BTEX - Benzene, Toluene, Ethylbenzene, Xylenes

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191
BTEX - Method 624/8240

Results:

| Client ID/ Lab ID | Parameter | Concentration | Detection Limit |
|----------------------|-----------------|---------------|--------------------|
| SHW-S-1 | TPH (Purgeable) | 390 | 50 mg/Kg |
| /BMI071896-02 | Benzene | ND | 100 ug/Kg |
| | Toluene | 130 | 100 ug/Kg |
| | Ethylbenzene | 280 | 100 ug/Kg |
| | Total Xylenes | 1,800 | 100 ug/Kg |
| SHW-S-2 | TPH (Purgeable) | 380 | 50 mg/Kg |
| /BMI071896-03 | Benzene | ND | 100 ug/Kg |
| | Toluene | 160 | 100 ug/Kg |
| | Ethylbenzene | 330 | 100 ug/Kg |
| | Total Xylenes | 2,500 | 100 ug/Kg |

ND - Not Detected

Approved by:

Roger L. Scholl
Roger L. Scholl, Ph.D.
Laboratory Director

Date:

7/24/96

[illegible]

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(702) 498-3312

FAX: 702-736-7523

1-800-283-1183

ANALYTICAL REPORTBattelle
505 King Ave
Columbus Ohio 43201Job#: Shaw AFB: Pilot Study
Phone: (614) 424-6199
Attn:

Sampled: 07/16/96 Received: 07/18/96 Analyzed: 07/24/96

Matrix: [X] Soil [] Water [] Waste

Analysis Requested: BTEX - Benzene, Toluene, Ethylbenzene, Xylenes

Methodology: BTEX - EPA Method 624/8240

Results:

| Client ID/ Lab ID | Parameter | Concentration mg/Kg | Detection Limit mg/Kg |
|----------------------|---------------|------------------------|-----------------------------|
| SHW-FP-1 | Benzene | 1300 | 1100 |
| /BMI071896-01 | Toluene | 7100 | 1100 |
| | Ethylbenzene | 3300 | 1100 |
| | Total Xylenes | 17000 | 1100 |

ND - Not Detected

Approved by:

Roger L. Scholl, Ph.D.
Laboratory Director

Date:

7/31/96

**Alpha Analytical, Inc.**

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1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30B1801
Phone: (614) 424-6199
Attn: Eric Foote

Alpha Analytical Number: BMI071896-01

Client I.D. Number: SHW-FP-1

Date Sampled: 07/16/96

Date Received: 07/18/96

| C-range Compounds | Method | Percentage of Total | Detection Limit (Not Applicable) | Date Analyzed |
|-------------------|--------|---------------------|----------------------------------|---------------|
| C09< | GC/FID | 49.93 | NA | 07/31/96 |
| C10 | GC/FID | 13.04 | NA | 07/31/96 |
| C11 | GC/FID | 11.19 | NA | 07/31/96 |
| C12 | GC/FID | 10.35 | NA | 07/31/96 |
| C13 | GC/FID | 7.98 | NA | 07/31/96 |
| C14 | GC/FID | 4.69 | NA | 07/31/96 |
| C15 | GC/FID | 1.92 | NA | 07/31/96 |
| C16 | GC/FID | 0.54 | NA | 07/31/96 |
| C17 | GC/FID | 0.36 | NA | 07/31/96 |

Approved by: _____

Roger L. Scholl
Roger L. Scholl, Ph.D.
Laboratory Director

Date: _____

8/1/96

**Alpha Analytical, Inc.**

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1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30B1801
Phone: (614) 424-6199
Attn: Eric Foote

Alpha Analytical Number: BMI071896-01

Client I.D. Number: SHW-FP-1

Date Sampled: 07/16/96

Date Received: 07/18/96

| C-range Compounds | Method | Percentage of Total | Detection Limit (Not Applicable) | Date Analyzed |
|-------------------|--------|---------------------|----------------------------------|---------------|
| C09 | GC/FID | 49.93 | NA | 07/31/96 |
| C10 | GC/FID | 13.04 | NA | 07/31/96 |
| C11 | GC/FID | 11.19 | NA | 07/31/96 |
| C12 | GC/FID | 10.35 | NA | 07/31/96 |
| C13 | GC/FID | 7.98 | NA | 07/31/96 |
| C14 | GC/FID | 4.69 | NA | 07/31/96 |
| C15 | GC/FID | 1.92 | NA | 07/31/96 |
| C16 | GC/FID | 0.54 | NA | 07/31/96 |
| C17 | GC/FID | 0.36 | NA | 07/31/96 |

Approved by:

Roger L. Scholl

Roger L. Scholl, Ph.D.
Laboratory Director

Date:

8/1/96

Alpha Analytical, Inc.

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Las Vegas, Nevada 89120

(702) 498-3312

FAX: 702-736-7523

1-800-283-1183

ANALYTICAL REPORTBattelle
505 King Ave
Columbus Ohio 43201Job#: Shaw AFB: Pilot Study
Phone: (614) 424-6199
Attn:

Sampled: 07/16/96 Received: 07/18/96 Analyzed: 07/24/96

Matrix: [X] Soil [] Water [] Waste

Analysis Requested: BTEX - Benzene, Toluene, Ethylbenzene, Xylenes

Methodology: BTEX - EPA Method 624/8240

Results:

| Client ID/ Lab ID | Parameter | Concentration mg/Kg | Detection Limit mg/Kg |
|----------------------|---------------|------------------------|-----------------------------|
| SHW-FP-1 | Benzene | 1300 | 1100 |
| /BMI071896-01 | Toluene | 7100 | 1100 |
| | Ethylbenzene | 3300 | 1100 |
| | Total Xylenes | 17000 | 1100 |

ND - Not Detected

Approved by:

Roger L. Scholl
Roger L. Scholl, Ph.D.
Laboratory Director

Date:

7/31/96

APPENDIX C
SYSTEM CHECKLIST

Checklist for System Shakedown

Site: SS-15, Shaw AFB

Date: 8 July 196

Operator's Initials: _____

| Equipment | Check if OK | Comments |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|----------|
| Liquid Ring Pump | ✓ | |
| Aqueous Effluent Transfer Pump | ✓ | |
| Oil/Water Separator | ✓ | |
| Vapor Flow Meter | ✓ | |
| Fuel Flow Meter | ✓ | |
| Water Flow Meter | ✓ | |
| Emergency Shut Off float Switch Effluent Transfer Tank | ✓ | |
| Analytical Field Instrumentation GasTechtor O ₂ /CO ₂ Analyzer TraceTechtor Hydrocarbon Analyzer Oil/Water Interface Probe Magnehelic Boards Thermocouple Thermometer | ✓ ✓ ✓ ✓ ✓ | |

APPENDIX D

DATA SHEETS FROM THE SHORT-TERM PILOT TEST

ATMOSPHERIC OBSERVATIONS

Site: Shaw AFB

Operators: S. Walton

| Date/Time | Ambient Temperature °F | Relative Humidity | Barometric Pressure |
|----------------|------------------------|------------------------------|--------------------------------|
| 7.12.96 / 8:31 | 74.6 | | |
| / 17:30 | 79.0 | | |
| 7.13.96 / 8:00 | 78.0 | | |
| 16:00 | 101.6 | | |
| 17:30 | 92.4 | | |
| 7.14.96 / 8:30 | 82.2 | | |
| 17:30 | 92.8 | | |
| 7.15.96 / 8:30 | 80.2 | | |
| 15:30 | 91.0 | | |
| 7.16.96 / 8:40 | 81.2 | | |
| 15:00 | 91.2 | | |
| 7.17.96 / 8:10 | 84.4 | | |
| 17:45 | 90.2 | | |
| 7.18.96 / 8:30 | 81.0 | | |
| 12:00 | 95.6 | | |
| | | | |
| | | | |
| | | | |
| | | | |

Baildown Test Record Sheet

Site: Shaw AFB

Well Identification: MW

Well Diameter (OD/ID): _____

Date at Start of Test: 7-8-96

Sampler's Initials: _____

Time at Start of Test: 13:30

Initial Readings

| Depth to Groundwater (ft) | Depth to LNAPL (ft) | LNAPL Thickness (ft) | Total Volume Bailed (L) |
|---------------------------|---------------------|----------------------|-------------------------|
| | | 6.51 | |

Test Data

| Sample Collection Time | Depth to Groundwater (ft) | Depth to LNAPL (ft) | LNAPL Thickness (ft) |
|------------------------|---------------------------|---------------------|----------------------|
| 13:58 | 51.36 | 50.71 | .65 |
| 14:00 | 51.15 | 50.29 | .86 |
| 14:02 | 50.89 | 49.81 | 1.08 |
| 14:06 | 50.28 | 49.21 | 1.07 |
| 14:09 | 50.01 | 48.99 | 1.02 |
| 14:11 | 49.82 | 48.89 | .93 |
| 14:14 | 49.75 | 48.63 | .82 |
| 14:18 | 49.29 | 48.44 | .85 |
| 14:22 | 49.16 | 48.21 | .95 |
| 14:26 | 49.02 | 48.01 | 1.01 |
| 14:31 | 48.88 | 47.79 | 1.09 |
| 14:36 | 48.81 | 47.59 | 1.22 |

Figure 9. Typical Baildown Test Record Sheet

Page 2

Baildown Test Record Sheet

Site: Shaw AFB

Well Identification: MW

Well Diameter (OD/ID): _____

Date at Start of Test: 7-8-96

Sampler's Initials: _____

Time at Start of Test: 13:30

Initial Readings

| Depth to Groundwater (ft) | Depth to LNAPL (ft) | LNAPL Thickness (ft) | Total Volume Bailed (L) |
|---------------------------|---------------------|----------------------|-------------------------|
| | | | |

Test Data

| Sample Collection Time | Depth to Groundwater (ft) | Depth to LNAPL (ft) | LNAPL Thickness (ft) |
|------------------------|---------------------------|---------------------|----------------------|
| 14:41 | 48.77 | 47.31 | 1.46 |
| 15:14 | 48.75 | 46.61 | 1.99 |
| 15:49 | 48.81 | 46.41 | 2.40 |
| 18:22 | 49.46 | 45.85 | 3.61 |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

Figure 9. Typical Baildown Test Record Sheet

Baildown Test Record Sheet

Site: Shaw AFB

Well Identification: MW644

Well Diameter (OD/ID): _____

Date at Start of Test: 7/08/96

Sampler's Initials: _____

Time at Start of Test: 14:52

Initial Readings

| Depth to Groundwater (ft) | Depth to LNAPL (ft) | LNAPL Thickness (ft) | Total Volume Bailed (L) |
|---------------------------|---------------------|----------------------|-------------------------|
| | | 4.34 | |

Test Data

| Sample Collection Time | Depth to Groundwater (ft) | Depth to LNAPL (ft) | LNAPL Thickness (ft) |
|------------------------|---------------------------|---------------------|----------------------|
| 14:52 | 47.62 | 45.89 | 1.73 |
| 14:54 | 47.55 | 45.81 | 1.74 |
| 14:55 | 47.52 | 45.75 | 1.77 |
| 14:56 | 47.42 | 45.65 | 1.77 |
| 14:59 | 47.34 | 45.57 | 1.77 |
| 15:02 | 47.25 | 45.43 | 1.82 |
| 15:13 | 47.00 | 45.07 | 1.93 |
| 15:18 | 46.95 | 44.96 | 1.99 |
| 15:29 | 46.83 | 44.78 | 2.05 |
| 16:01 | 46.81 | 44.76 | 2.35 |
| 18:11 | 47.24 | 44.09 | 3.15 |
| | | | |

Figure 9. Typical Baildown Test Record Sheet

Pilot Test Monitoring Well Data Sheet

Site: Shaw AFB

Test Type (Skimmer, Bioslurper Vacuum Extraction, Draw Down): Bioslurper

Depth to Groundwater: _____ Depth to Fuel: _____ Depth of Slurper Tube: _____

Date at Start of Test: 7.11.96

Time at Start of Test: 12:00

Operators Initials: _____

| Time | Well ID: <u>643</u> | | | Well ID: | | | Well ID: | | |
|-------|---------------------|------------------|--------------------------------------|-------------|-------------|--------------------------------|-------------|-------------|--------------------------------|
| | LNAPL Level (ft) | Water Level (ft) | LNAPL Pressure (in H ₂ O) | LNAPL Level | Water Level | Pressure (in H ₂ O) | LNAPL Level | Water Level | Pressure (in H ₂ O) |
| T=0 | | | | | | | | | |
| 8:31 | 44.04 | 48.23 | 4.19 | | | | | | |
| 17:30 | 44.05 | 48.23 | 4.18 | | | | | | |
| 8:00 | 44.09 | 48.23 | 4.14 | | | | | | |
| 16:00 | 44.10 | 48.23 | 4.13 | | | | | | |
| 17:30 | 44.10 | 48.23 | 4.13 | | | | | | |
| 8:30 | 44.14 | 48.25 | 4.085 | | | | | | |
| 17:30 | 44.15 | 48.23 | 4.08 | | | | | | |
| 8:30 | 44.19 | 48.22 | 4.03 | | | | | | |
| 15:30 | 44.19 | 48.22 | 4.03 | | | | | | |

Figure 14. Typical Record Sheets for Bioslurper Pilot Testing

Page of

Start Date: 7-9-96

Start Time: 11:48

Well ID: MW644

Depth of Tube: _____

[illegible]

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing (Continued)

Bioslurping Pilot Test
(Data Sheet 2)
Pilot Test Pumping Data

Page ____ of ____

Site: Shaw AFB

Start Date: 7.11.96

Operators: S Walton

Start Time: 12:00

Test Type: Bioslurper

Well ID: MW 644

Depth to Groundwater: _____ Depth to Fuel: _____

Depth of Tube: _____

| Date/Time | Run Time | Vapor Extraction | | | Seal Tank Pump Stack Temp 20 °F | Pump Head Vacuum (in. Hg) | Extraction Well Vacuum (in. H ₂ O) |
|-----------------------------|----------|---------------------------------------------|---------------------------------------------------------|--------------------|-----------------------------------------------------|---------------------------------|-----------------------------------------------------|
| | | Stack Pressure (in. H ₂ O) | Carbon Dioxide (in. H ₂ O) | Flowrate (scfm) | | | |
| 7.11.96 13:06 | 1.1 | .01 | | | 117.6 | 19.0 | 26 |
| | | ND | | | 122.4 | | 24 |
| 16:45 | 4.7 | | | | | | 12 |
| 17:00 | 5.0 | .025 | | | | 16.0 | 12 |
| 7.12.96 8:31 | 20.5 | .01 | | | 121.4 | 19.0 | 13.5 |
| 17:30 | 29.5 | .01 | | | 128.6 | 19.0 | 13 |
| 7.13.96 8:00 | 44.0 | .02 | | | 130.8 | 19.0 | 13.5 |
| 16:00 | 52.0 | .01 | | | 139.4 | 18.5 | 13 |
| 17:30 | 53.5 | .055 | | | 128.0 | 18.0 | 22 |
| 7.14.96 8:30 | 68.5 | .02 | | | 125.0 | 18.0 | 22 |
| 17:30 | 77.5 | | | | 129.0 | 17.5 | 22 |
| 7.15.96 8:30 | 92.5 | .07 | | | 122.8 | 18.0 | 22 |
| 15:30 | 99.5 | .04 | | | 128.8 | 18.0 | 21 |
| | | | | | | | |

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing (Continued)

Page ____ of ____

Start Date: 7.15.96

Start Time: 16:16

Well ID: MW644

Depth of Tube: _____

[illegible]

30

Page _____ of _____

Start Date: 7.16.96

Start Time: 16:00

Well ID: MW644

Depth of Tube: _____

[illegible]

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing (Continued)

Page ____ of ____

Test Type: Initial Skimmer

Operators: S. Walton

[illegible]

Page ____ of ____

Operators: S. Walton

[illegible]

Page ____ of ____

Operators: S. Walton

[illegible]

Page ____ of ____

Test Type: Drawdown

Operators: S. Walton

[illegible]

APPENDIX E
SOIL GAS PERMEABILITY TEST RESULTS

[illegible]

[illegible]

APPENDIX F
IN SITU RESPIRATION TEST RESULTS

Record Sheet for In Situ Respiration Test

[illegible]

Site Shaw AFB

Monitoring Point

MPA-Blue

Shutdown Date 7-18-96

O₂/CO₂ Meter No.

TPH Meter No.

Shutdown Time 9:00

Recorded by S. W. Eaton

INSITU.RS (G462201-1001 DISK

Site Shaw AFB

Monitoring Point A - Red

Shutdown Date 7-18-96

O₂/CO₂ Meter No.

TPH Meter No.

Shutdown Time 9:00

Recorded by S. Walton

[illegible]

Site Shaw AFB

Monitoring Point D-Green

Shutdown Date 7-18-96

O₂/CO₂ Meter No.

TPH Meter No.

Shutdown Time 9:00

Recorded by S. W. Horton

INSITU.RS (G462201-1001 DISK